

**EFFECT OF *RHIZOBIUM*, VAM AND ROCK PHOSPHATE INOCULATION
ON GROWTH, PRODUCTIVITY AND NUTRIENTS ACQUISITION OF
SOME SELECTED LEGUMES**



BY

TABASSUM YASEEN

**DEPARTMENT OF BOTANY
UNIVERSITY OF PESHAWAR
2013**

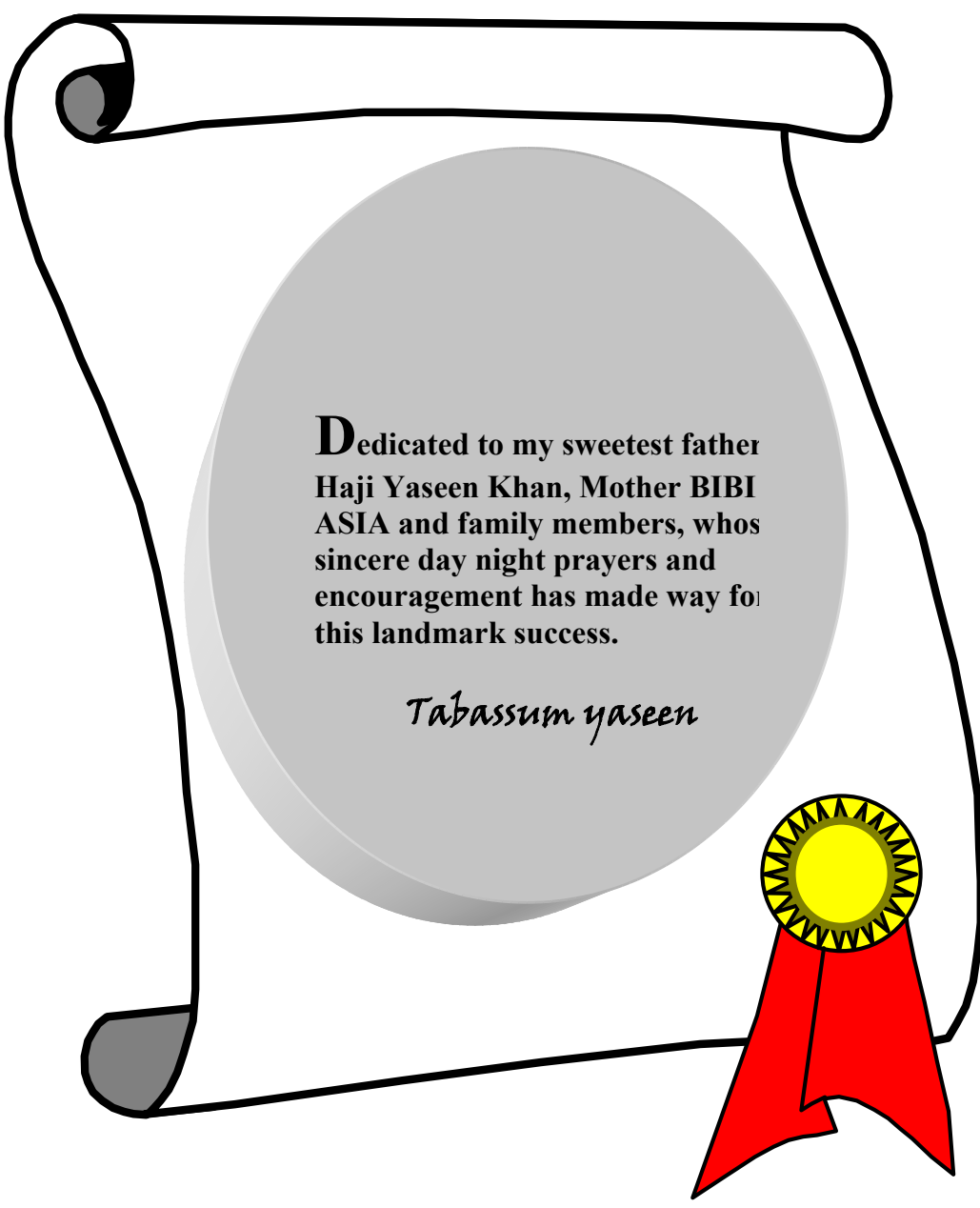
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Dedicated to my sweetest father
Haji Yaseen Khan, Mother BIBI
ASIA and family members, whos
sincere day night prayers and
encouragement has made way fo
this landmark success.

Tabassum yaseen

University of Peshawar
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SOME SELECTED LEGUMES**

A dissertation submitted in partial satisfaction
of the requirement for the degree of
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in
Botany
By
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by

TABASSUM YASEEN

ABSTRACT

Microorganisms and their interactions in soil play a critical role in nutrient transformations and cycling, and in sustaining soil productivity. Arbuscular mycorrhizal fungi (AMF) are a keystone group of fungi influencing nutrient cycling. In turn, the activity and composition of microorganisms in soil are influenced by management practices such as the choice of crop species and fertilization. Biofertilizer has been identified as an alternative source for chemical fertilization to increase soil fertility and crop production.

Arbuscular mycorrhizal (AM) fungi and rhizobia are two of the most important plant symbionts in natural habitats. Many leguminous plants have the ability to associate with the two microbial symbionts, which yield arbuscular mycorrhizae and root nodules. Moreover, AM fungi, rhizobia and leguminous plants are able to form a tripartite symbiosis. It has demonstrated that the intimate association is determined by the mutual recognition and subsequently the penetration of plant tissues in the establishment stage. A pot experiment was conducted in a net house in the University of Peshawar Pakistan, investigate the effect of seed inoculation with *Rhizobium* and/or soil inoculation with the vesicular-arbuscular mycorrhizal fungus *Glomus mosseae*, *Glomus fasciculatum* and *G. aggregatum* under different levels of RP fertilization. A pot experiment was conducted in 2010-2011 to investigate the arbuscular mycorrhizal (AM) status of *Vigna radiate* (NAIB-92, NAIB-98, NAIB-2006), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (NARC-2008-2, NARC-2008-3, NARC-2008-4, NARC-2002) its relationship with plant vegetative, flowering and fruiting stages. The different inoculations (single and dual) of *Rhizobium* and VAM fungi mostly *Glomus msesae*, *Glomus fasciculatum* and *G. aggregatum* were incorporated under deficient P soil (1.13%). The growth and yield responses of studied legumes to co-

inoculation with AMF and *Rhizobium* strains depended on the particular AMF-*Rhizobium* strain combination. In some cases, the productivity of studied legumes inoculated with an effective *Rhizobium* strain was reduced by an apparently incompatible AMF species compared to the *Rhizobium* treatment. In contrast, the yield of studied legumes inoculated with some ineffective *Rhizobium* strains was enhanced by an apparently compatible AMF species compared to the *Rhizobium* treatment. However, maximum *Lens culinaris* productivity was achieved only in treatments with effective *Rhizobium* strains or co-inoculation treatments with effective *Rhizobium* strains and a compatible AMF species.

Plants were analysed for growth parameters (plant height, number of leaves, number of flowers/plant, number of pod/plant, number of seeds/pod, length of pod), dry weight of plant, nutrient uptake (Mg, Ca, K, Cu, Mn, Fe and Zn), proximate composition (crude protein, ash, crude fiber, fat and carbohydrate), percent VAM infection and spore density.

Plants were analyzed for proximate composition and mineral composition. Results showed significant at ($p > 0.05$) increase in the moisture and carbohydrate contents the fat, ash, crude fiber and protein content treated plants. Mycorrhizal colonization gradually increased with the increase in plant age from early vegetative to fruiting stage. Plants colonized by arbuscular mycorrhizal (AM) fungi have been shown to respond positively to the application of insoluble forms of inorganic phosphorus (P) such as rock phosphates (RPs) that responses to RP by mycorrhizal (MRP₁ and MRP₂) plants more pronounced than RP alone.

The results revealed that dual inoculation of *Rhizobium* with VAM (*Glomus moseleyi*, *Glomus fasciculatum* and *G. aggregatum*) enhanced seed yield of legume. Varieties were single or dual inoculated with different AM fungus and different *Rhizobium* strains the dual symbiosis formed by AM fungi and *Rhizobium* depending on the plant variety and the symbionts involved. Influence of VAM fungus, *Rhizobium* and Rock phosphate inoculation on lentil, green mung bean, pea, desmodium and burgundy growth response in relation to growth parameters, yield and productivity, dry weight of plants, grains, roots colonization was studied in pot studies. The treatments consisted of inoculation with VAM fungus only, *Rhizobium*, dual inoculation with VAM fungus and *Rhizobium*. Rock phosphate alone and dual with VAM and control. Seeds concentration

of VAM used as inoculum was 290 spores per pot. Rhizospheric soil from wheat field having high spores number of different AMF i-e *Glomus fasciculatum*, *G. mosseae* and *G. aggregatum* and roots of wheat and maize infected with Arbuscular mycorrhiza were used as rhizobase inoculum . Roots were cut into 1cm pieces. These root pieces along with soil base inoculum (rhizospheric soil) were spread uniformly in layers at a depth of 3cm and 6cm before sowing. Inoculum for each pot consisted of 180 gm of mycorrhizal infected roots and adhering soil. The spore density was found to be 290 spores per 100g of soil. A synergistic relationship dependent on N and P status exists between rhizobia and AM fungi on growth. Co-inoculation with rhizobia and AM fungi significantly increased. Studied legumes growth under low P.

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ABBREVIATIONS

<i>Ac.</i>	<i>Acaulospora, spp.</i>
AM	Arbuscular mycorrhiza
<i>Arb.</i>	Arbuscules
EH.	External hyphae
<i>Gl.</i>	<i>Glomus spp.</i>
IH.	Internal hyphae
M	mycorrhizal
Mycorrhizal dependency	(MD)
N	Non mycorrhizal
Rhizobium	RHZ.
RP	Rock phosphate
<i>Scl.</i>	<i>Sclerocystis. spp.</i>
VAMF	Vesicular arbuscular mycorrhizal fungi
<i>Ves.</i>	Vesicles

CHAPTER 1

INTRODUCTION

1.1 Mycorrhiza

“Arbuscular mycorrhiza (AM) are widespread symbiotic interactions that are commonly described as the result of co-evolution between fungi and plants where both partners benefit from the reciprocal nutrient exchange” (Sharma, 2003; Bonfante&Genre, 2008). Arbuscular mycorrhizal (AM) symbioses are formed by approximately 80% of vascular plant species in all major terrestrial biomes. In consequence an understanding of their functions is critical in any study of sustainable agricultural or natural ecosystems (Pongrac *et al.*, 2007; Feddermann *et al.*, 2010; Smith *et al.*, 2010).

1.2 Classification of Mycorrhiza

Harley & Smith (1983) recognized three types of mycorrhizae as ectomycorrhiza, endomycorrhiza and ectendomycorrhiza. Brundrett (1990) classified the mycorrhiza based on different groups of fungi and host plants and distinct morphological pattern into Ectomycorrhiza, Vesicular arbuscular mycorrhiza, Ectendomycorrhiza, Ericoidmycorrhiza orchid mycorrhiza, Mycorrhiza of thysanotus.

Sylvia (2003) recognized five mycorrhiza types: Ectomycorrhizae, ectendomycorrhizae, ericaceous mycorrhiza, orchidaceae mycorrhizae and Arbuscular mycorrhizae. Most recently (Purohit, 2005) classified on the basis of plant host fungal species involved of distinct morphological patterns into seven types of associations. They are ectomycorrhizae (ECM), Vesicular arbuscular mycorrhizae (V) AM, and orchidmycorrhizae, ericoidmycorrhizae, ectendomycorrhizae, arbutoidmycorrhizae and Monotropoidmycorrhizae.

1.3.1 Arbuscular Mycorrhiza (AM)

Arbuscular mycorrhiza (AM) is the most common type of mycorrhizal association, occurring in 2/3 of land plants (Hodge, 2000). AM fungi are ubiquitously associated with a great majority of plant families in different ecosystems across the

world, ranging from the tropics (Zhao and Hyde, 2001) to mesic (Muthukumar & Udaiyan, 2000) and arid habitats (O'Connor *et al.*, 2002). As vesicles are absent in two of the seven genera containing these fungi, the term is currently preferred by many researchers to represent the association of arbuscular mycorrhizal (AM) fungi rather than vesicular arbuscular (V) AM fungi (Habte & Osorio, 2002). Arbuscular mycorrhizal fungi are known to occur widely under various environmental conditions in association with forage crops (Carrenho *et al.*, 2001; Chen *et al.*, 2005; Souchie *et al.*, 2006). The mycorrhizae has the beneficial effect on the phosphate nutrition of crop plants in soil low in phosphorous (Chen *et al.*, 2005; Duponnois, 2006). AM are produced by aseptate mycelial fungi, which produce vesicles and arbuscules in plant roots after infection. Mycorrhizae are present in 92% of plant families (80% of species), with arbuscular mycorrhizae being the ancestral and predominant form, and indeed the most prevalent symbiotic association found in the entire plant kingdom (Vogt & Scliemann, 2003; Wang & Qiu, 2006; Pozo & Aguilar, 2007). This is particularly evident with the arbuscular mycorrhizal (AM) fungi, which are obligate symbionts of a majority of all plant species and common across most terrestrial biomes (Smith & Read, 2008).

Arbuscular mycorrhizal fungi (AMF) are of great ecological importance, as arbuscular mycorrhizal fungi (AMF) is the most widespread plant symbiosis that improves plant productivity and resistance to nutrient stress. AMF are essentially obligate biotrophs. Their life cycle includes growth and proliferation within the host root and surrounding soil. The mutual recognition and the development of the symbiosis will trigger specific developmental programs in both organisms (Feddermann *et al.*, 2010).

1.3.2. AMF Infection

According to Brundrett (1990) VAM consists of following four structures:

1. External mycelial phase
2. Internal mycelial phase
3. Arbuscule
4. Vesicle

VAM fungal infection into a host occurs by germination of spores, hyphal growth through soil to host roots, penetration of host roots and spread of infection inter-and intracellularly in the root cortex. Two morphological structures occurs namely the fine dichotomously branched filaments present in root cortical cells called arbuscules and the terminal or intercalary swelling of the hyphae called vesicles. Arbuscules serves as nutrient transfer system between the symbionts and vesicles store phosphorus and function in vegetative reproduction. AM infection and development pattern is under genetic control (Bertheau *et al.*, 1980; Abbott, 1982). The response of chickpea (*Cicer arietinum* L.) to dual inoculation with *Rhizobium* and arbuscular mycorrhiza, nitrogen and phosphorus, observations were recorded for spore abundance and colonization of AM, and yield. *Rhizobium* inoculant alone was superior to the control for all parameters studied (Solaiman *et al.*, 2006). The stimulatory effect of rhizotrophic microorganisms on growth, yield and nutrient uptake of chickpea using sterilized soil deficient in available phosphorus. Phosphorus status of soil was improved by *Serratia* coinoculated with *M. ciceri* and *G. fasciculatum* but N contents in general did not differ appreciably. The results show there was an increase in (i) populations of phosphate solubilising microorganisms in some treatments, (ii) percentage root infection and (iii) spore density of the arbuscular mycorrhizal fungus in the soil (Zaidi & Khan, 2006).

1.3.3. Classification of AMF

Dalpe (1993) placed the arbuscular mycorrhizal fungi in class Zygomycetes with following three families:

a. Family *Acaulosporaceae*

Genera: *Acaulospora*, *Entrophospora*

b. Family *Gigasporaceae*

Genera: *Gigaspora*, *Scutellospora*

c. Family *Glomaceae*

Genera: *Glomus*, *Sclerocystis*.

Recent phylum *Glomeromycota* of Arbuscular mycorrhizal fungi (AMF) by (Schubler *et al.*, 2001). This phylum also includes *Geosiphon pyriforme*, which forms

mutualistic symbiosis with the cyanobacteria like *Nostoc*. The fungi belonging to the Phylum *Glomeromycota* are characterized by non-septed mycelium, and do not reproduced sexually. Spores are asexual, large, and are surrounded by a thick cell wall that is formed by several layers. Spores germinate in soil, and the germinative tube grows either directly from inside crossing the cell wall or by internal specialized structures. The phylum *Glomeromycota* have four orders, five families, and approximately seven well defined genera (three more in the process of being named). There are approximately 150 species of fungi, which are able to form AMF-symbiosis with higher plants (Schubler *et al.*, 2001).

The *Classification Glomeromycetes* (Division *Glomeromycota*) is given in Table

Order	Family	Genus
1. <i>Glomerales</i>	i. <i>Glomeraceae</i>	<i>Glomus</i>
2. <i>Diversisporales</i>	i. <i>Gigasporaceae</i>	<i>Gigaspora</i> <i>Scutellospora</i>
	ii. <i>Acaulosporaceae</i>	<i>Acaulospora</i> <i>Entrophospora</i>
	iii. <i>Pacisporaceae</i>	<i>Pacispora</i>
	iv. <i>Diversisporaceae</i>	<i>Diversispora</i>
3. <i>Paraglomerales</i>	i. <i>Paraglomeraceae</i>	<i>Paraglomus</i>
4. <i>Archaeosporales</i>	i. <i>Geosiphonaceae</i>	<i>Geosiphon</i>
	ii. <i>Archaeosporaceae</i>	<i>Archaeospora</i>

1.4. Significance of Arbuscular mycorrhiza (AM)

Although not necessarily the primary function of the symbiosis, AM plants have been observed to receive protection from pathogens relative to their non-mycorrhizal counterparts in experimental studies (Filion *et al.*, 1999, 2003; Borowicz, 2001). Mycorrhizae facilitate nutrients uptake especially phosphorus, nutrient recycling, water absorption, production of plant growth hormones, increased tolerance to adverse soil pH, high temperature, drought and toxic heavy metals. They also improve soil structure,

bicontrol pests and enhance biomass yield (Singh, 2003). Mycorrhizal symbiosis plays an important role in nutrient cycling in agricultural and natural ecosystems (Plenchette *et al.*, 2005). These fungi impart many benefits to plants. Colonization of roots by AM fungi has been shown to improve growth and productivity of several field crops (Cavagnaro *et al.*, 2006; Pasqualini *et al.*, 2007; Thenua *et al.*, 2010) by increasing nutrient element uptake (Al-Karaki, 2006). These fungi enhance crop growth and yield through enhanced tolerance to various biotic (Khaosaad *et al.*, 2007) and abiotic stresses (Al-Garni, 2006; Takeda *et al.*, 2007) and improving physical, chemical and biological properties of soil (Rillig & Mummey, 2006; Cardoso & Kuypers, 2006). The mycorrhizae has the beneficial effect on the phosphate nutrition of crop plants in soil low in phosphorous has been reported (Chen *et al.*, 2005; Duponnois, 2006). AM can alter plant physiology in a way, which enables the host plant to cope with the stress (Miransari & Smith, 2008; Smith & Read, 2008). Yield in the response of shoot and root dry weight was significantly increased due to dual inoculation than single inoculation. While the N, P and K uptake percentage (age%) was also more due to dual inoculation (Khan *et al.*, 2008; Thenua *et al.*, 2010).

1.4.1 Hormone Production

AM fungi and plant hormones have enhancing effects and soil bacteria on plant performance is by inducing plant systemic resistance, also influenced by plant hormones (Van Wees *et al.*, 2008). AM fungi can alter the amount of plant hormones, investigated for jasmonic acid (JA) and abscisic acid (ABA) (Ludwig & Muller, 2000; Hause *et al.*, 2007; Grunwald *et al.*, 2009). Both hormones are necessary for the establishment of AM symbiosis (Isayenkov *et al.*, 2005). In addition, the newly classified plant hormones, strigolactones, can also affect mycorrhization in plants, which is also influenced by mitochondrial activities (Akiyama *et al.*, 2005; Akiyama & Hayashi, 2006; Bessierer *et al.*, 2009). The plant host may be affected by one or more mechanisms such as nitrogen fixation, enhancing nutrient uptake, production of plant growth promoting substances, phytohormones, and organic acids, as well as protection of plant from pathogens (Dileep *et al.*, 2001; Glick, 2005; Kohler *et al.*, 2006, 2009; Jalili *et al.*, 2009; Alguacil *et al.*, 2009).

1.4.2 As a Bio control Agent

The role of below-ground soil organisms interacting with plant roots has gained increased attention in recent years (Reynolds *et al.*, 2003; Van der Putten, 2003; Callaway *et al.*, 2004). Many studies suggest that AM fungal taxa vary both in the expression of traits associated with some of these mechanisms (Hart & Reader, 2002; Pozo & Aguilar, 2007) and in their ability to protect host plants against pathogens (Klironomos, 2000; Dileep *et al.*, 2001; Elsen *et al.*, 2003; Khalequzzaman & Hossain, 2008; Sikes *et al.*, 2009, Megan & Tibbett, 2008). Several mechanisms have been suggested by which plant growth-promoting rhizobacteria (PGPR) can promote plant growth, including phytohormone production, nitrogen (N₂) fixation, and stimulation of nutrient uptake and biocontrol of pathogenic microorganisms (Benizri *et al.*, 2001; Persello-Cartieaux *et al.*, 2003; Somers *et al.*, 2004). The number of infection loci within the root system (Vigo *et al.*, 2000) is reduced as a result of AM fungal colonization. VA fungi have been reported in disease severity by acting as “bio-control agent” (Rudresh *et al.*, 2005). Several mechanisms have been proposed to explain how this protection arises (Azcon & Barea 1996; Whipps, 2004; Dalpe, 2005). Studies suggest that AM fungal taxa vary both in the expression of traits associated with some of these mechanisms (Hart & Reader, 2002; Pozo & Aguilar, 2007) and in their ability to protect host plants against pathogens (Newsham *et al.*, 1995; Klironomos, 2000; Maherali & Klironomos, 2007; Sikes *et al.*, 2009). Maherali & Klironomos (2007) found taxonomic variation within the AM fungal phylum *Glomeromycota*, both in terms of nutrient responses and pathogen protection. There is presently only one report (Maherali & Klironomos, 2007) that compared AM fungal effects on reduced pathogen abundance using a taxonomically diverse set of AM fungal species in the same experimental setting. VAM fungi can give protection from parasitic fungi (Grandmaison *et al.*, 1993; Newsham *et al.*, 1995; Little & Maun, 1996; Cordier *et al.*, 1998; Morin *et al.*, 1999).

1.4.3 ADVERSE SOIL CONDITION

1.4.3.1 Drought Resistance

It is reported that leguminous species tolerate the drought due to the presence of nodules however; the tolerance limit of the species depends on the nodule size. Initially nitrogen fixation decreased in response to water deficit prior to many other physiological processes and soil nitrogen accumulation (Andyking & Purcell, 2001). AM association also has a positive effect on plants under drought conditions (Auge 2001, 2004).

1.4.3.2 Soil Structure

Rhizospheric interactions can result in the modification of soil structural properties (Rillig & Mummey, 2006). The relationship between the level of mycorrhizal colonization and the chemical and physical characteristics of the soil are known to be quite variable (Motosugi *et al.*, 2002). External hyphae bind the soil particles together and appear to be important as means of erosion control (Sylvia, 2003). Arbuscular mycorrhizal fungi are known to occur widely under various environmental conditions and are found in association with forage crops (Carrenho *et al.*, 2001; Chen *et al.*, 2005; Souchie *et al.*, 2006). First report about the effect of AM fungi and phosphorus on *Mimosa* species, which may be useful in biodiversity and soil conservation programs (Sara *et al.*, 2009). AMF improve soil structure and aggregation through the mechanical effect exerted by extra-radical hyphae (Rilling & Mummey, 2006; Smith *et al.*, 2010).

Salinity control

There is a possibility that VAM might play a positive role in salt tolerance by providing buffering effect against nutrient excess (Azcon & Barea, 1996; Feng *et al.*, 1998).

Detoxification

The VAM infection led to the suppression of the accumulation of toxic products of anaerobic respiration, such as ethanol (Osundina, 1998).

Metal toxicity

Bacterial-AM-legume tripartite symbiosis could be a new approach to increase the heavy metal tolerance of legumes plants under heavy metal polluted soil (Saleh & Garni, 2005; Al-Garni & Saleh, 2006). Other beneficial effects are protection of plants

from heavy metal concentration in rhizosphere (Agrios, 1978) like that of aluminum toxicity (Kottke & Martin, 1994).

As a Bio-fertilizer

The primary physiological function of VA mycorrhizae is to improve growth development and yield of plants (Charitha & Reddy, 2001; Niranjan *et al.*, 2002; Xavier & Germind, 2002; McGonigle *et al.*, 2003; Zaidi *et al.*, 2003; Jia *et al.*, 2004; Jalaluddin, 2005; Satter, 2006; Bergero *et al.*, 2008; Khan *et al.*, 2008; Ghosh & Josep, 2008; Paola & Iulia, 2009; Abdulla & Khaliel, 2010) by increase uptake of macro (Habte & Osorio, 2002) and micro nutrient (George, 2000). Biofertilizers are products containing living cells of different types of microorganisms, which have an ability to convert nutritionally important elements from unavailable to available form through biological processes (Vessey, 2003). Inoculant biofertilizers are more environmentally sound and their introduction in agricultural production systems could be one of the means to mitigate the onset of global warming as well as the reduction in fertilizer input costs of farmers (Kennedy *et al.*, 2004). The effect of biofertilizers on the enrichment of soil fertility with special reference to soil phosphorus status and its effect on the yield of green gram (*Vigna radiata*). It concluded that *Rhizobium* strain BINAR P36 largely controlled the foot and root rot and produced higher green pod yield of Bush bean. This strain used for production of biofertilizers and increasing green pod yield of Bush bean (Khalequzzaman & Hossain, 2008).

1.5 Importance of AM fungi in agriculture

Among the most important implications of microbial interactions in agriculture is the alleviation of different soil stresses including drought, acidity, salinity, compaction and heavy metals. For example, how the use of soil microbes including extensive research has been done on use of AM fungi for treating heavy metals in soil. Although AM has been proved to be effective on the alleviation of stress, it would be interesting to investigate how such abilities can be improved when using AM fungi in combination with other soil microbes. AM fungi are able to alleviate the stress by enhancing plant

growth, storing heavy metals in the vacuoles of their vesicles and binding them by the production of the insoluble glycoprotein, glomalin (Khan, 2005). One of the most important mechanisms by which AM fungi are able to enhance plant resistance to plant pathogens in soil is through altering the microbial combination in the mycorrhizosphere. The related effects also include bacterial activities and their production that usually contains pathogen-controlling products (Barea *et al.*, 2005). The activities of soil microbes including AM fungi and bacteria can influence soil structure through the production of bacterial metabolites including polysaccharides, formation of AM hyphae and production of the glycoprotein, glomalin (Rillig & Mummey, 2006). Such products are able to bind soil particles and form soil aggregates, resulting in improved soil structure (Andrade *et al.*, 1998; Barea *et al.*, 2005). Accordingly, such effects also indicate the beneficial effects of co-inoculation with AM fungi and bacteria on the improvement of soil structural properties and fertility in desertified areas. Using several legume species tolerant under drought conditions, Jeffries & Barea (2001) indicated that soil properties including nutritional values were improved upon coinoculation with AM fungi and rhizobium. These include enhanced N fixation as well as improved soil structure. Hence as a useful biotechnological method, coinoculation of drought-tolerant plants with AM fungi and bacteria including rhizobium can contribute to the enhanced recovery of desertified and self-sustaining ecosystems (Barea *et al.*, 2005). It is important to determine the bacterial population with the highest physiological activities, in association with AM fungi. This indicates the bacterial strains that are more efficient, particularly when interacting with AM fungi, and can likely make the use of effective coinoculation (Hartmann *et al.*, 2009; Franzini *et al.*, 2010). There are different methods used to determine bacterial association with AM fungi. For example, for tagging and visualizing the bacterial strain *Paenibacillus brasilensis*, which has suppressing effects on the activity of plant pathogens and stimulate the activity of some specific AM species, used the green fluorescent protein technique. In this method, marker genes are used to tag the bacteria. These genes lead to the production of green fluorescent and hence make it likely to investigate the bacterial behavior interacting with AM fungi or other soil microbes including pathogens (von der Weid *et al.*, 2005). The other molecular techniques include stable isotope probing, DNA sequencing and PCR (Johnson *et al.*,

2001; Griffiths *et al.*, 2004). The interactions between AM fungi and bacteria can take place in the rhizosphere before the onset of inoculation or after the establishment of the tripartite symbiosis between AM fungi, bacteria and the host plant (Garbaye 1994; Gryndler *et al.*, 2000; Artursson *et al.*, 2006). The synergistic interactions of AM fungi and bacteria can also stimulate plant growth through enhancing processes such as nutrients uptake and controlling plant pathogens. These processes are of significance, especially in agricultural cropping strategies (such as organic farming), which do not depend much on agrochemicals to maintain soil fertility and health. In addition, AM fungi are also able to influence the combinations of soil bacterial populations (Artursson *et al.*, 2005). These effects can be related to the alteration of root physiology by affecting the chemical combination of root products (Gryndler, 2000; Linderman, 2000). Although extensive research has been carried out on the interactive activities between AM fungi and bacteria, more research must be conducted to more clearly elucidate the processes involved in the interactions between AM fungi and soil bacteria. This can be useful for the optimum determination of bioinoculants combination, which is necessary for sustainable agricultural cropping strategies (Artursson *et al.*, 2006). Arbuscular mycorrhizal fungi and other soil microbes can alleviate the unfavorable effects of heavy metals on plant growth or how such a technique can be used for the remediation of polluted soils (Berg, 2009; Joner & Leyval, 2009).

1.6 Microhabitats occupied by the interacting bacteria with AM fungi

The microhabitats, which are commonly occupied by soil bacteria interacting with AM fungi (Dumbrell *et al.*, 2010) include surface of plant roots (nonsymbiotic bacteria), plant root cells (symbiotic bacteria), AM hyphae and the rhizosphere surrounding plant roots (different kinds of bacteria). Hence, the microhabitats occupied by bacteria are determined based on their feeding properties, their kind of symbiosis, soil and climate properties and their host specifications (Nazir *et al.*, 2010). AM are also great niches for other soil microbes and while some of the bacteria are attached to AM hyphae, some of them are bound to plant roots (Bianciotto *et al.*, 2001; Bonfante, 2003). While for other eukaryotic cells the association with bacteria is common (Moran &

Wernegreen, 2000) for AM fungi only a few strains of bacteria are integrated into the fungi (Ruiz-Lozano & Bonfante, 2000; Levy *et al.*, 2003; de Boer *et al.*, 2005).

1.6.1 Mycorrhiza helper bacteria

There are a large number of bacteria, including plant growth-promoting rhizobacteria (PGPR) and *Rhizobium*, called mycorrhiza helper bacteria (MHB), which promote the activity and development of AM fungi (Frey-Klett *et al.*, 2007; Richardson *et al.*, 2009). They are usually fungal-specific but not plant-specific (Rillig *et al.*, 2005). In other words, promote the growth of specific AM fungi, in symbiosis with their nonspecific host plant. Such specificity has been attributed to the size of spore and the roughness of spore surface (Bharadwaj *et al.*, 2008). Accordingly, the term “mycorrhization helper bacteria” was suggested by (Frey-Klett *et al.*, 2007) indicating a broader concept compared with MHB as it also includes the onset of AM symbiosis as well as the biocontrolling effects of MHB on other fungal species with regard to their specificity.

1.7 Tripartite symbiosis

Pulses are mostly of short duration, fits better in rotation and can be grown as main, inter, catch green manure or cover crop that keeps the soil productive and sustainable (Bhat *et al.*, 2010). Food legumes are crops of the family leguminosae also called Fabaceae. They are mainly grown for their edible seeds, and thus are also named grain legumes. They occupy large cropped areas worldwide. Grain legumes are used as pulse (dhal) with cereals, grown in both tropical and temperate regions of the globe. They enhance the protein content of cereal-based diets and may improve the nutritional status of the cereal-based diets. Cereal proteins are deficient in certain essential amino acids, particularly lysine (Amjad *et al.*, 2003). The other interesting part related to the AM fungal interaction with other soil microbes is the formation of tripartite symbiosis between AM fungi, rhizobium and legumes. The enhancing effects of coinoculation with

AM fungi and rhizobium on the growth and yield of legume have been well known. AM fungi can significantly increase legume growth by enhancing water and nutrients uptake. The enhanced P uptake can also positively affect rhizobium N-fixation by affecting the energy producing pathways (Barea *et al.*, 1996; Aryal *et al.*, 2003; Mortimer *et al.*, 2008). Hormonal effects on the development of root and nodules may also affect the nitrogen (N₂)fixation by legume in the tripartite symbiosis (Richardson *et al.*, 2009; Franzini *et al.*, 2009). The efficiency of the tripartite symbiosis is affected by parameters such as plant variety, *Rhizobium* strains, AM species and the related interactions as well as their growth stage (Marulanda *et al.*, 2006; Mortimer *et al.*, 2008). With respect to the significance of both AM symbiosis and *Rhizobium* N fixation environmentally and economically, consideration of parameters, which enhance their tripartite symbiosis can be important. N and P are two necessary macronutrients for plant growth and yield production (Richardson *et al.*, 2009). Chemical fertilization especially at excess amounts is not recommendable; hence, providing N and P biologically by AM fungi and rhizobium may greatly contribute to the increased yield production while making them agriculturally and environmentally sustainable (Miransari, 2010b; Miransari & Mackenzie, 2010a, b, c). It is also important that the tripartite symbiosis be tested under different conditions including stress to evaluate if its efficiency can be enhanced. As AM fungi and rhizobium bacteria are morphologically and physiologically different, their response is also different under stress conditions. Under stress, AM fungi are more resistant and can help their host plants grow more effectively (Miransari, 2010a) however, rhizobium is not tolerant to stress and their efficiency decreases under stress (Miransari & Smith, 2007; 2008; 2009). Hence, in a tripartite symbiosis, it can be useful if the N-fixing capacity of rhizobium is increased by AM symbiosis. This is also important for the production of inoculum, meaning that biotechnologically the two microbes have to be treated in a way that results in the highest efficiency of the host plant symbiosis under different conditions including stress (Muhammad *et al.*, 2006).

Many legumes form tripartite symbiotic associations with rhizobia & arbuscular mycorrhizal fungi (AMF). Rhizobia fixed atmospheric nitrogen which are located in root nodules & provide the plant with, while AMF colonize plant roots & deliver several essential nutrients to the plant (Scheublin *et al.*, 2006). The interaction among the three

organisms usually results in a mutualistic tripartite symbiosis (Antunes *et al.*, 2005). Interactions between P solubilizing bacteria and AM fungi in the mobilization of P from Rock phosphate have been consistently reported (Barea *et al.*, 2002; Caravaca *et al.*, 2004; Cabello *et al.*, 2005). Both symbioses share parts of signaling pathways, indicating intimate interactions between all three partners during co-evolution (Guinel & Geil, 2002; Antunes *et al.*, 2006). Recent investigations (Taiwo & Adgebite, 2001) indicated that a much larger genetic variability of bradyrhizobial and AM fungal strains existed in different cultivar regions than assumed earlier according to (Antunes *et al.*, 2005). Many legumes form symbioses with both rhizobia and arbuscular mycorrhizal fungi (AMF). Dual inoculation with both microorganisms results in a tripartite mutualistic symbiosis and generally increases plant growth to a greater extent than inoculation with only one (Chalk *et al.*, 2006). Combinations of *Rhizobium* with different AM fungal strains or species are important since the compatibility of such interactions may be relevant to nitrogen (N₂) fixation and to nutrient and water uptake by the legume plants (Marulanda *et al.*, 2006). At the same time, it is known that the interaction between the two symbionts also depends on the stage of development of both microorganisms inside the host roots (Mortimer *et al.*, 2008). It has been found that dual symbiosis of *Rhizobium*–AM fungi enhances drought tolerance of the legume host plant in terms of the total plant growth (Zahran, 1999; Valdenegro *et al.*, 2001). Many leguminous plants have the ability to fix atmospheric nitrogen (N₂) through a symbiosis with rhizobia, and can also host arbuscular mycorrhizal fungi (AMF), which in return for carbon provide the plant with mineral nutrients (Smith & Read, 1997). In legumes, VAM fungi increase nodulation and nitrogen (N₂) fixation as a consequence of improved phosphorus nutrition. (Athar , 2005). It has been assumed that the significance of the tripartite symbiosis is solely associated with increased P supply to the nodules through the AMF (Ganry *et al.*, 1982; Kawai & Yamamoto, 1986; Vejsadová *et al.*, 1993; George *et al.*, 1995; Ibjibijen *et al.*, 1996; Xavier & Germida, 2003). AMF families vary widely in the pattern of root colonization and life strategy (Hart & Reader, 2002). A recent study by Scheublin *et al.* (2004) showed that root nodules contained AMF communities that were different from those in the legume roots, which strongly supports the hypothesis that AMF functional diversity is important in the tripartite symbiosis. In this context, the simultaneous

application of *Rhizobium* and PS microorganisms (Perveen *et al.*, 2002) and phosphate solubilizing microorganisms (PSM), and arbuscular mycorrhizal (AM) fungi (Zaidi *et al.*, 2003) has been shown to stimulate plant growth more than inoculation of each microorganism alone in certain situations when the soil is P deficient. However, the inoculation effects of the tripartite interaction between nitrogen (N₂) fixing, phosphate solubilizing microorganisms (PSM), and AM fungus on legume crops are relatively scarce (Zaidi *et al.*, 2004). Rhizobia is one of the dominant symbiotic nitrogen fixing bacteria with legumes but a number of factor including low number of Rhizobia and ineffective native Rhizobia lead to poor nodulation and nitrogen fixation in legumes. Legume and *Rhizobium* symbiosis contributes at least 90 x 10⁶ metric tonnes of N per year all over the world (Subba Rao, 1982). Phosphorous deficiency is a major limiting factor for growth of legumes in various soils, where P stress may be accompanied by N stress, due to high P requirement of nodule activity. Inoculation with Vesicular arbuscular mycorrhizae(VAM) has been shown to increase nodulation, root colonization, dry matter accumulation in shoot, nutrient uptake and soil fertility status (Singh & Singh, 1993). Arbuscular mycorrhizal (AM) fungi and rhizobia are two of the most important plant symbionts in natural habitats. Many leguminous plants have the ability to associate with the two microbial symbionts, which yield arbuscular mycorrhizae and root nodules. Moreover, AM fungi, rhizobia and leguminous plants are able to form a tripartite symbiosis (Wang *et al.*, 2008).

Most leguminous plants are simultaneously symbiotic with nodule forming *Rhizobium* and AMF. *Rhizobium* fixes nitrogen, which benefits plant growth, and the mycorrhizal fungi benefits the host by increasing the efficiency of uptake of mineral elements and water from the soil as well as altering host metabolism and other physiological parameters (Khalequzzaman & Hossai, 2007; Singh & Singh, 2010; Xiao *et al.*, 2010). Nearly all-leguminous plants with nodules formed by *Rhizobium* grow better. They are also colonized by VA mycorrhizal fungi (Ray & Valsalakumar, 2009). There are different types of soil bacteria in the soil, interacting with AM fungi, particularly in the rhizosphere. In most cases, the interactions are synergistic (Smith & Read, 2008). Many leguminous plants have the ability to fix atmospheric nitrogen (N₂) through a symbiosis with rhizobia, and can also host arbuscular mycorrhizal fungi

(AMF), which in return for carbon provide the plant with mineral nutrients (Smith & Read, 1997). In legumes, VAM fungi increase nodulation and nitrogen (N₂) fixation as a consequence of improved phosphorus nutrition (Athar *et al.*, 2005). It has been assumed that the significance of the tripartite symbiosis is solely associated with increased P supply to the nodules through the AMF (Ganry *et al.*, 1982; Kawai & Yamamoto, 1986; Vejsadova *et al.*, 1993; George *et al.*, 1995; Ibijbijen *et al.*, 1996; Xavier & Germida, 2003). AMF families vary widely in the pattern of root colonization and life strategy (Hart & Reader, 2002). (Scheublin *et al.*, 2004) showed that root nodules contained AMF communities that were different from those in the legume roots, which strongly supports the hypothesis that AMF functional diversity is important in the tripartite symbiosis. In this context, the simultaneous application of *Rhizobium* and PS microorganisms (Perveen *et al.*, 2002) and phosphate solubilizing microorganisms (PSM), and arbuscular mycorrhizal (AM) fungi (Zaidi *et al.*, 2003) has been shown to stimulate plant growth more than inoculation of each microorganism alone in certain situations when the soil is P deficient. However, the inoculation effects of the tripartite interaction between N₂ fixing, phosphate solubilizing microorganisms (PSM), and AM fungus on legume crops are relatively scarce (Zaidi *et al.*, 2004). Rhizobia is one of the dominant symbiotic nitrogen fixing bacteria with legumes but a number of factor including low number of rhizobia and ineffective native rhizobia lead to poor nodulation and nitrogen fixation in legumes. Legume and *Rhizobium* symbiosis contributes at least 90 x 10⁶ metric tonnes of N per year all over the world (Subba Rao, 1982). Phosphorous deficiency is a major limiting factor for growth of legumes in various soils, where P stress may be accompanied by N stress, due to high P requirement of nodule activity. Inoculation with vesicular arbuscular mycorrhizae(VAM) has been shown to increase nodulation, root colonization, dry matter accumulation in shoot, nutrient uptake and soil fertility status (Singh, 1993).

Many workers have reported enhancement of phosphate & nitrogen uptake and growth of leguminous plants by vesicular arbuscular mycorrhizal fungi (Ezawa *et al.*, 2000; Arihara & Kara Sawa, 2000; Meshram *et al.*, 2000; Joner, 2000; Izagirre, 2000; Guriqbal *et al.*, 2001; Mamatha *et al.*, 2002; Atimanav & Adholeya, 2002; Chen *et al.*, 2005; Duponnois, 2006; Ray & Valsalakumar, 2009). Interactions between VAMF and

Rhizobium were examined in chickpea, which enhanced the plant growth, uptake of essential nutrients, like phosphorus and nitrogen and nodulation (Jalaluddin, 2005; Rahman *et al.*, 2008; Krishnareddy & Ahlawat, 2008; Rotoret *et al.*, 2010). Most legumes are symbiotic with both nodule-forming *Rhizobium* spp. and AM fungi, and the tripartite relationship of host-*Rhizobium*-AM fungi is unlike either dipartite symbiosis (Abdulla & Khaliel, 2010).

The use of phosphate solubilizing microorganisms, including arbuscular mycorrhizal (AM) fungi, has been proposed as a low-cost and low-energy mechanism to help increase the agronomic effectiveness of RP fertilizers (Richardson, 2001; Gyaneshwar *et al.*, 2002). The AM symbiosis is recognized for its ability to increase the inflow of slowly mobile nutrients to plant roots, predominantly P (Tinker *et al.*, 1992). P taken up by AM fungi is considered to be from the same labile pool used by plant roots. However, there is increasing indication that mycorrhizal roots may be capable of using insoluble sources of inorganic P in soil that are not available to the roots (Barea *et al.*, 2002; Cabello *et al.*, 2005; Duponnois *et al.*, 2005).

The data revealed that the rhizobium, mycorrhizal and other fertilizers inoculation significantly increased microbiological parameters such as number of nodules, fresh weight of nodules and nitrogenase activity in some pulses such as green gram, chick pea (Balachandran *et al.*, 2005; Solaiman *et al.*, 2006; Baba *et al.*, 2006; Gitasree, 2007; Kushwaha, 2007; Jain *et al.*, 2007; Verma & Singh, 2008; Singh, 2008).

Leguminous plants that demonstrate this tendency to respond similarly to particular strains of *Rhizobia* are considered “effectiveness” group (Wani & Lee, 2002). *Rhizobia* form a very interesting symbiotic relationship with leguminous plants. Great efforts have been made to improve the symbiotic N₂-fixing ability and productivity of legumes. Recent studies reported about the wild-legume rhizobial ability to establish successful symbiosis with their original hosts, as well as with legume crops (Wang *et al.*, 2008). In Pakistan very little work has been done on the mycorrhizal status of legumes and role of AMF and rhizobia on their growth (Rokhzadi & Toashih, 1991; Iqbal *et al.*, 1991; Nasim *et al.*, 1996; Saif & Khan, 1975; Khaliq *et al.*, 1997; Hafeez *et al.*, 2000; Bloem & Law, 2001; Muhammad *et al.*, 2006; Khalequzzaman & Hossai, 2007; Akhtar & Siddiqui, 2009).

Pulses occupy an indispensable position in the dietary habit of vast majority in the Indian subcontinent. Besides, being nutritionally fulfilling these contributes to the restoration of the soil fertility. Pulses are mostly of short duration, fits better in rotation and can be grown as main, inter, catch green manure or cover crop that keeps the soil productive and sustainable (Bhat *et al.*, 2010). Pulses provide energy, dietary fibre, protein, minerals and vitamins required for human health. Recent research studies suggest that consumption of pulses may have potential health benefits including reduced risk of cardiovascular disease, cancer, diabetes, osteoporosis, hypertension, gastrointestinal disorders, adrenal disease and reduction of LDL cholesterol (Hu, 2003; Jacobs & Gallaher, 2004; Philanto & Korhonen, 2003; Tharanathan & Mahadevamma, 2003).

Mungbean, capable of fixing atmospheric nitrogen through *Rhizobium* species living in root nodules. However, under our agro-ecological conditions, the nodulation of mungbean is poor and is a major cause of its lower yield. Inoculation of mungbean with *Rhizobium* increased plant height, leaf area, photosynthetic rate and dry matter production (Thakur & Panwar, 1995). An increase in number of nodules per plant and seed yield with inoculation of *Rhizobium* (Muhammad *et al.*, 2006).

India is the largest producer and importer of the leguminous crop (Shakya *et al.*, 2008). Amongst the leguminous crops, chick-pea (*Cicer arietinum* L.) occupies an important position due to its nutritive values (17-23% protein) in large vegetarian population of the country (Ali & Kumar, 2006). According to (Akhtar & Siddiqui, 2009) during last decade the production of chick-pea has been declined, and it has been argued that usual native soil rhizobial populations are inadequate and are ineffective in biological nitrogen fixation. To ensure an optimum rhizobial population in the rhizosphere, seed inoculation of legumes with an efficient rhizobial strain is necessary. This helps improve nodulation, nitrogen (N₂) -fixation solicit crop growth and yield of leguminous crops (Henzell, 1988).

Scheublin *et al.* (2006) reported that many legumes form tripartite symbiotic associations with rhizobia & arbuscular mycorrhizal fungi (AMF). Rhizobia fixed atmospheric nitrogen which are located in root nodules & provide the plant with, while AMF colonize plant roots & deliver several essential nutrients to the plant. The interaction among the three organisms usually results in a mutualistic tripartite symbiosis

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It was found that dual inoculation of *G. intraradices* + *B. japonicum* was superior over single inoculation of *G. intraradices* *B. japonicum* in both the soybean cultivars and produced 21.20% and 16.94% higher seed weight of plants of JS 335 and NRC 7 cultivars respectively when compared to control (Meghvansi & Mahna, 2009). Several mechanisms have been suggested by which plant growth-promoting rhizobacteria (PGPR) can promote plant growth, including phytohormone production, N₂ fixation and stimulation of nutrient uptake and biocontrol of pathogenic microorganisms (Rodriguez & Fraga, 1999; Sindhu *et al.*, 1999; Benizri *et al.*, 2001; Persello- Cartieaux *et al.*, 2003; Somers *et al.*, 2004). Seed inoculation with a combination of beneficial microorganisms including rhizobia, plant growth-promoting rhizobacteria (PGPR) and PSB (Phosphate Solubilizing Bacteria) has been shown to increase crop growth and Productivity (Dashti *et al.*, 1998; Rodelas *et al.*, 1999; Chebotar *et al.*, 2001; Sindhu *et al.*, 2002; Zaidi *et al.*, 2003; Rudresh *et al.*, 2005). Plant growth promoting rhizobacteria (PGPR) represent a

wide variety of soil bacteria which, when grown in association with a host plant, result in stimulation of growth of their host plant (Vessey, 2003). Many different genera of plant growth promoting rhizobacteria such as *Azospirillum*, *Azotobacter*, *Bacillus*, *Enterobacter* and *Pseudomonas* have been used as biofertilizers for economically important crops.

Many worker have done on seed inoculation alone or with a combination of beneficial microorganisms including AMF, rhizobia, plant growth-promoting rhizobacteria (PGPR) and PSB (Phosphate Solubilizing Bacteria) have been shown to increase green gram and chickpea growth and productivity, seed yield, nitrogen fixation and nutrient uptake (Chebotar *et al.*, 2001; Benizri *et al.*, 2001; Sindhu *et al.*, 2002; Persello- Cartieaux *et al.*, 2003; Somers *et al.*, 2004; Zaidi *et al.*, 2003; Vessey, 2003; Chebotar *et al.*, 2001; Rudresh *et al.*, 2005; Ramakrishna *et al.*, 2005; Tufenkci *et al.*, 2005; Balachandran *et al.*, 2005; Solaiman *et al.*, 2006; Gitasree, 2007; Goud & Reddy, 2007; Kushwaha, 2007; Jain *et al.*, 2007; Venkateshwarlu, 2008; Rahman *et al.*, 2008; Ghosh & Josep, 2008; Jain *et al.*, 2008; Dhage *et al.*, 2008; Raghwendra & Kedar, 2008; Ray & Valsalakumar, 2009; Nazmunet *et al.*, 2009; Pir *et al.*, 2009; Akhtar & Siddiqui, 2009; Singh & Seema, 2009; Jain *et al.*, 2009; Singh & Singh, 2010; Thenua *et al.*, 2010).

The present studies were conducted to evaluate the beneficial effect of biofertilizers (VAM, *Rhizobium* and Rock phosphate) inoculation alone and in combination on growth, productivity, nutrient uptake, and chemical composition and yield components of mungbean, pea, lentil, burgundey and desmodium crops.

REVIEW OF LITERATURE

2.1 EFFECT OF AM FUNGAL AND RHIZOBIA INOCULATION ON THE HOST GROWTH RESPONSES

2.1.1 Effect of AM and Rhizobia on plant growth, productivity and yield in legumes

Mukherjee & Rai (2000) reported that biofertilizer and phosphorus nutrition interaction showed significant influence on growth and phosphorus uptake by chickpea compared with either of the components applied separately. Among the VAM fungi, *Glomus fasciculatum* had positive effects on yield and phosphorus uptake, unlike *Glomus macrocarpum*. Meshram *et al.* (2000) reported that seeds treated with *Glomus*+*Gigaspora*+*Acaulospora* and among the P treatments, Rock Phosphate recorded the highest available N and the highest values for number of nodules per plant, dry weight of nodules, shoots, roots, total dry matter and grain yield over control.

Giller (2001) reported the amount of nitrogen (N₂) fixed by legume depends on plant species and cultivars, on rhizobial strains and on the environmental conditions. Charitha & Reddy (2001) reported that dual inoculation resulted in significant increase in growth, number of nodules, mycorrhizal colonization than inoculation with VAM fungus *Rhizobium* alone.

Chatterjee & Bhattacharjee (2002) reported that mung bean cv. B-1 inoculated with *Rhizobium* strains and PSB showed increased rate of nodulation, N content and grain yield. The percentage increase in grain yield over control was observed to be higher significantly in plants inoculated with *Rhizobium* strains and PSB. Sapatnekar *et al.* (2002) reported treatment combinations comprised, 100% P₂O₅ in the form of either

single superphosphate (SSP) or rock phosphate (RP), two P solubilizers (fungal culture, *Aspergillusawamori* and a bacterial culture, *Pseudomonasstriata*) along with N₂-fixer *Rhizobium loti*. Chickpea responded positively to application of P sources with P solubilizers alone and in combination with *R. loti*. Based on the results, fungal P solubilizers were superior over bacterial strains, and SSP was superior over RP. Niranjana *et al.* (2002) reported that dual combinations of rhizobial isolates (PC Rhz-5, PC Rhz-7, PCRhz-8) and vesicular arbuscular mycorrhizal (VAM) fungi (*Gigasporacalospora*, *Glomus fasciculatum* and *Glomus mosseae*) tested, the seedlings of *Prosopis cineraria* inoculated with *Rhizobium* (PC Rhz-5)+*Glomus mosseae* as twin symbionts recorded maximum enhancement of all parameters tested (growth, nodulation and nitrogenase activity) in comparison to inoculated with *Rhizobium* alone. Xavier & Germin (2002) reported co-inoculation with AMF and rhizobia significantly increased the shoot biomass of plants compared to the uninoculated control in lentil.

McGonigle *et al.* (2003) stated that arbuscular mycorrhizal (AM) plants usually have greater P uptake and growth when raised in undisturbed soil compared to disturbed soil and reported that AM fungi stimulate shoot P uptake in experimental comparisons to non-mycorrhizal plants differ in their ability. AM fungi were tested for growth promotion of maize (*Zeamays* L.) in pots in a soil disturbance experiment that included non-mycorrhizal controls. Fungi colonized roots well and promoted shoot P uptake compared to non-inoculated controls, *Glomusmosseae* was able to stimulate growth in undisturbed soil compared to disturbed soil. Xavier & Germida (2003) reported synergistic effects of dual colonization of roots with AM fungi and *Rhizobium* on growth, nutrient uptake and nitrogen fixation in pea. Bergero *et al.* (2003) stated that peanuts benefited from mycorrhizal association by increasing dry matter yield, phosphorus (P) uptake and stimulation of root and shoot growth. Jain & Pushpendra (2003) investigate the effect of biofertilizer and P fertilizer on the growth and nutrition of chickpea. The biofertilizer treatments were control *Rhizobium* sp. (Rz), phosphate solubilizing bacteria (PSB); and Rz + PSB. Rz + PSB and P also increased nutrient content and uptake. Rz + PSB increased the soil N, but the P fertilizer did not improve soil N status. Rz + PSB application and graded application of P significantly increased P availability in the soil. Zaidi *et al.* (2003) reported that plant yield and nutrient uptake

were significantly enhanced as a result of inoculation with *Rhizobium* sp. and phosphate solubilising microorganisms (PSM), *Pseudomonas striata* or *Penicillium* variable. Plant yield and nutrient uptake were further augmented by the addition of AM fungus, *Glomus fasciculatum* in the combined inoculation treatment with *Rhizobium* sp.+*P. striata*. Mahboob *et al.* (2003) reported that seed inoculation and different fertilizer levels significantly affected yield and yield components of mungbean and rice crops. Kalipada & Singh (2003) reported inoculation of biofertilizers increased the yield and nutrient (N, P and K) uptake. The inoculation of PSB+VAM recorded higher yield and nutrient uptake over PSB and VAM individual applications. The yield and nutrient uptake by chickpea also increased with increasing levels of P. Potdukhe & Guldekar (2003) reported that synergistic effects of combined inoculations of *Rhizobium*, phosphate-solubilizing bacteria (PSB, *Azospirillum brasilense*) and antagonistic bacteria (AB) on nodulation and grain yield of mung bean cv. The highest nodule number (20.31/plant) and nodule dry weight (107.21 mg/plant) were obtained under the treatments with *Rhizobium* alone and *Rhizobium* + AB. Singh & Pareek (2003) investigated the effects of biofertilizers (*Rhizobium* sp.; phosphate solubilizing bacteria, PSB; and combination of *Rhizobium* + PSB) on the growth and yield of mung bean cv. All biofertilizer treatments increased growth and yield characters, except pod length and test weight. The highest values for all the parameters studied were obtained with *Rhizobium* + PSB dry matter branches/plant at harvest; number of nodules per plant; pods/plant; and seed yield/ha. Jia *et al.* (2004) investigated that both rhizobial and mycorrhizal symbioses can act synergistically on promoting plant growth and fitness. Rohyadi *et al.* (2004) observed the effects of the arbuscular mycorrhizal (AM) fungi *Gigaspora margarita* and *Glomus etunicatum* on the growth of cowpea (*Vigna unguiculata* L. Walp.) at low pH, with and without AM inoculation, growth was enhanced both by increasing the pH and by inoculating with the AM fungi. The relative growth improvement by mycorrhizas (mycorrhizal growth response) was highest at pH 4.7, and decreased as the pH increased, although effects were not always significant. Jagviret *et al.* (2004) reported that dual inoculation, *Rhizobium* and VAM resulted in increase in grain yield respectively, over no inoculation, the yield of green gram, attributed to cumulative effect of growth attributes viz., plant height, number of branches per plant, number of trifoliate leaves,

leaf area index, dry matter accumulation per plant, crop growth rate and net assimilation rate and yield attributes viz., pods per plant, pod length, seeds per pod, 1000-seed weight and seed yield per plant. Gilani&Bharose (2004) studied the effect of biofertilizers on the yield of green gram (*Vigna radiata*). Different levels of phosphorus and bio-fertilizer (*Rhizobium* and phosphate solubilizing bacteria) were applied. The combined application of phosphorus and *Rhizobium* resulted in significant higher plant height (cm), number of branches per plant, number of seeds per pod, number of pods per plant and number of nodules per plant. Gupta (2004) reported that dual inoculation in gram with *Rhizobium* and phosphorus-solubilizing bacteria either as seed or as soil inoculation significantly increased the nodulation and seed yield. Muhammad *et al.* (2003) reported that effect of phosphorus and *Rhizobium* inoculum on the yield and yield components of mungbean cv. NM- 92. The results showed that plant height and number of branches per plant were significantly affected with both inoculum and P application. However, it was found that the number of grains pod⁻¹ increased only with increase of P levels. *Rhizobium* inoculation resulted in significantly increase in grain yield as compared with non-inoculated. Shivakumar *et al.* (2004) observed that single superphosphate was significantly superior to rock phosphate. Increasing levels of phosphorus increased the seed yield significantly, irrespective of source of phosphorus. Furthermore, the seed inoculation with phosphate solubilizing bacteria and *Rhizobium* improved the growth and yield over that of no seed inoculation. Zaidi *et al.* (2004) noted that green gram (*Vigna radiata* cv. T-44) yield and nutrient (nitrogen (N) and P) uptake were significantly increased as a result of inoculation with *Bradyrhizobium* sp. (*vigna*) and phosphate solubilizing microorganisms (PSM), *Pseudomonas striata* or *Penicillium variabile*. Plant yield and nutrient uptake were further increased by the addition of AM fungus, *Glomus fasciculatum*, in combined inoculation treatment with *Bradyrhizobium* sp. (*vigna*) + *Pseudomonas striata*.

Jalaluddin (2005) noted that combined inoculation of VAM fungus, *Glomus macrocarpum* and *Bradyrhizobium japonicum* in soybean variety William 82 promoted maximum growth and yield. Rajasekaran & Nagarajan (2005) determined the effect of *Glomus mosseae* and *Rhizobium* on the chlorophyll of *Vigna unguiculata* leaves. Dual inoculation with vesicular arbuscular mycorrhizal fungi and *Rhizobium* species was

effective in increasing chlorophyll contents, leading to enhanced growth in legumes. Satyawati *et al.* (2005) stated that arbuscular mycorrhizal (AM) fungi and *Azotobacte*, separately as well as in combination was evaluated for enhancing biomass productivity of *Morus alba*, *Populus deltoides*, *Psidium guajava* and *Leucaena leucocephala*. The combined inoculation of AM fungi and *Azotobacter* gave the best results. Khan *et al.* (2005) reported the effect of seed inoculation with *Rhizobium* along with various levels of phosphorus on chickpea (cv. Karak-1) growth the results revealed significant increase in nodules per plant, seed weight and yield. However, the response of other phosphorus levels was also prominent. Rudresh *et al.* (2005) reported that combined inoculation of *Rhizobium*, a phosphate solubilizing *Bacillus megaterium* and a biocontrol fungus *Trichoderma* spp. on growth, nutrient uptake and yield of chickpea were studied. Combined inoculation of these three organisms showed increased germination, nutrient uptake, plant height, number of branches, nodulation, yield, and total biomass of chickpea compared to either individual inoculations or control. Tufenkci *et al.* (2005) reported that inoculation with arbuscular mycorrhizal fungi (AMF; *Glomus intraradices*) and P (0, 50 and 100 mg/kg) and N (0, 100 and 200 mg/kg) fertilizer application on the growth and yield of chickpea cv. Aziziye-94. AMF inoculations significantly increase the growth parameters and yield. AMF inoculation with 50 mg P and 100 mg N/kg is the recommended treatment for chickpea production. Balachandran *et al.* (2005) reported that the effect of seed inoculation with *Rhizobium* and phosphate solubilizing bacteria (*Pseudomonas* and *Bacillus* sp.). Rh + PSB significantly increased plant height, number of branches, leaf area, dry matter production and number and dry weight of root nodules. Jain *et al.* (2005) recorded that P and biofertilizer (*Rhizobium* and phosphorus-solubilizing bacteria, singly or in combination) on the performance of *C. arietinum*. P significantly improved the P uptake over the control. The seed inoculation of *Rhizobium* singly and in combination with phosphorus-solubilizing bacteria increased the soil N content over the control. Bhat *et al.* (2005) concluded that VAM inoculation recorded the highest seed yield. Seed yield was lowest in the control. All the phosphorus rates increased the seed yield significantly over the control. All the biofertilizers significantly higher than that of the control based on plant height and dry matter accumulation.

Chalk *et al.* (2006) observed that dual inoculation with rhizobia and arbuscular mycorrhizal fungi AMF results in a tripartite mutualistic symbiosis and generally increases plant growth to a greater extent than inoculation with only one. Satter (2006) reported that leguminous crops have the capability of improving soil fertility by fixing atmospheric nitrogen into available form with the help of rhizobial species present in the root nodules. The arbuscular mycorrhiza (AM) fungi are known to improve plant uptake of immobile nutrients particularly P from high P-fixing soils and also from the less soluble P sources. Scheublin *et al.* (2006) noted that many legumes form tripartite symbiotic associations with rhizobia and arbuscular mycorrhizal fungi (AMF). Rhizobia fixed atmospheric nitrogen which through root nodules and provide the plant with, while AMF colonize plant roots and deliver several essential nutrients to the plant. Geneva *et al.* (2006) reported that dual inoculation of pea plants which significantly increased the, photosynthetic rate, plant biomass, nodulation, and nitrogen fixation activity in comparison with single inoculation with *Rhizobium leguminosarum* bv. *viciae* strain D 293. Zaidi & Khan (2006) reported that green gram seed yield increased even further, by 15% - 17%, by inoculation with *Bradyrhizobium* + *G. fasciculatum* and *G. fasciculatum* + *B. subtilis*. Baba *et al.* (2006) studied effect of *Rhizobium* inoculation and N and P fertilizer application in green gram (*Phaseolus radiatus* [*Vigna radiata*]) the Plant height, leaf area index, dry matter, nodule number/weight, branches/plant, pods/plant, pod length, seeds per pod, 1000 seed weight, N uptake and P uptake were significantly influenced by *Rhizobium* inoculation, N and P fertilizer application. Jat & Jat and Ahlawat (2006) reported that seed inoculation of chickpea with *Rhizobium*+PSB (phosphate solubilizing bacteria) increased dry matter accumulation, grain yield and protein content of chickpea, over no inoculation and inoculation with *Rhizobium* alone. Jarande *et al.* (2006) stated that treatments which included rock phosphate (RP) and seed treatment with phosphate solubilizing bacteria (PSB) and *Rhizobium*. Application RP +PSB+*Rhizobium* recorded higher values of growth as well as yield contributing parameters, plant height, number of branches per plant, dry matter per plant, seed yield per plant, number of seeds per plant, grain yield. Zaidi & Saghir (2006) reported plant vigour, yield and nutrient uptake were significantly enhanced following inoculation with composite application of *Mesorhizobium ciceri* with *serratia* and arbuscular mycorrhizal

fungus *Glomus fasciculatum* had maximum positive effect on chickpea. Solaiman *et al.* (2006) reported that chickpea (*Cicer arietinum* L.) to dual inoculation with *Rhizobium* and arbuscular mycorrhiza, were recorded for spore abundance and colonization of AM, nodulation, growth, yield attributes and yield. *Rhizobium* inoculant alone was superior to the control. Dual inoculation with *Rhizobium* and AM performed the best in recording.

Mortimer *et al.* (2007) reported that synergistic effects of the combined application of rhizobia and AM fungi enhance plant growth to a greater extent than singular inoculation. Sayeed & Siddiqui (2007) reported that combined inoculation of *G. intraradices* with *P. straita* plus *Rhizobium* to pathogen-inoculated plants caused greater increase in plant growth, number of pods, chlorophyll, nitrogen, phosphorus and potassium contents than by inoculation of *G. intraradices* plus *Rhizobium* or *G. intraradices* plus *P. straita* alone. Pasqualini *et al.* (2007) showed that AM fungi enhanced plant growth and nutrient uptake in some legume species. Gitasree (2007) reported that inoculation of chickpea (*Cicer arietinum* L.) combined inoculation with PGPR and an effective strain of *Rhizobium* sp. of *Cicer*, enhanced nodulation and grain yield of the crop over un inoculated control and also to *Rhizobium* alone. Goud & Reddy (2007) determined that the effect of *Rhizobium* inoculation and phosphorus levels on the growth and yield of green gram (*Phaseolus radiatus* [*Vigna radiata*]) cv. *Rhizobium* inoculation also resulted in more number of pods per plant, seeds per pod and seed yield. Vishram *et al.* (2007) reported three biofertilizers viz., PSB, *Rhizobium* and VAM were tested. Result showed that VAM produced significantly better growth attributes, yield attributes and yield over rest of the biofertilizers. VAM gave more dry matter, higher seeds per plant and than PSB and *Rhizobium*, respectively. Patelet *et al.* (2007) reported that *Rhizobium* inoculation, phosphate solubilizing bacterial (PSB), and *Rhizobium* + PSB) on the performance of chickpea (cv. Phule G 5), among the organic fertilizers, *Rhizobium* + PSB was superior in terms of plant height, number of branches per plant, number of pods per plant, grain weight per plant. Kushwaha (2007) reported *Rhizobium*, *Phosphotica* and dual inoculation of *Rhizobium*+*Phosphotica* significantly enhanced the growth parameters viz., plant height, branches/plant, nodules/plant and grain and straw yields of chickpea. Yadav *et al.* (2007) reported that effects of biofertilizers (*Rhizobium*, alone and in combination with phosphate solubilizing bacteria), on nodulation and yield of green

gram cv. K-851. The highest grain yield, grains per pod, test weight and nodule number per plant were recorded with the application of *Rhizobium* and phosphate solubilizing bacteria over control. Poonam *et al.* (2007) reported seed inoculation with *Rhizobium* recorded increase in yield by 12-16%. Conjunctive use of *Rhizobium* with phosphate solubilizing bacteria (PSB) and plant growth promoting rhizobacteria (PGPR) revealed synergistic effect on symbiotic parameters and grain yield of mungbean. Jain *et al.* (2007) reported that *Rhizobium leguminosarum*, phosphorus and micronutrients on green gram cultivars Pusa 105 and Pusa Vishal resulted in the highest plant height, nodulation and dry matter production. Pusa Vishal had higher values for these parameters than Pusa 105.

Erdal *et al.* (2008) reported that controlled environment and in the field trials, single, dual, and triple inoculations with *Rhizobium*, significantly increased all the parameters investigated (plant height, shoot, root and nodule dry weight, N%, chlorophyll content, pod number, seed yield, total biomass yield compared with the control treatment. Neveen *et al.* (2008) studied the utilization of *Rhizobium*-VAM association is a vital area for practical studies dealing with maximizing fertilizer efficiency to conserve energy, material resources, and reduce costs of food production. Khan *et al.* (2008) indicated that VA mycorrhizal fungi differed in their effects on plant growth and suggested the importance of evaluating the compatibility of VA mycorrhizal fungus and plant host. Khan *et al.* (2008) reported that yield in the response of shoot and root dry weight was significantly increased due to dual inoculation than single inoculation in *Medicago sativa*. Neveen *et al.* (2008) stated that in faba bean cultivars dual infection plus added 50% of recommended dose of N and P fertilization showed the maximum significant increases in number of pods and seeds/plant, weight of pods and seeds /plant, as well as seed yield /fed on both cultivars as compared with the uninfected plants or those inoculated with *Rhizobium* or VAM alone. Wang *et al.* (2008) reported that to improve legume productivity is to select effective (N₂-fixing) rhizobia to be used as inoculants for the respective legumes. Recent studies reported about the wild-legume rhizobial ability to establish successful symbiosis with their original hosts, as well as with legume crops. Khalequzzaman & Hossain (2008) stated that application of *Rhizobium* strains and biofertilizers increased plant growth, yield and yield attributes are, highest number of nodules/plant, the tallest plant, highest number of pods/plant, the highest weight of green

pods/plant in Bush bean as compared to control. Mortimer *et al.* (2008) observed that inoculation with AM fungi generally enhances plant growth by alleviating response to nutrient deficiency or other stresses and by enhancing nitrogen fixation process. Meghvansi *et al.* (2008) reported that in soybean a strong selective synergistic relationship existed between AMF and *B. japonicum*. Manke *et al.* (2008) investigated the dual application of *Rhizobium* and VAM showed synergistic effect on all mungbean cultivars variety “Vaibhav” was found most responsive to root nodulation, growth parameters and grain yield. Whereas, seed inoculation of *Rhizobium* + VAM was recorded more in enhancement of all parameters as comparative to single inoculation of *Rhizobium* or VAM or 100 per cent chemical fertilizer application. Khan *et al.* (2008) reported VA mycorrhizal fungi differed in their effects on plant growth. Ghosh & Josep (2008) investigated that dual inoculation of *Rhizobium*+PSB, significantly recorded the highest number of pods per plant, fertility co-efficient, number of seeds per pod, seed yield, stover yield and test weight compared to alone inoculation or control. Morshed *et al.* (2008) find out the influence of phosphorus (P) levels on growth and yield of soybean (*Glycine max* L., variety: G-2). The yield component, namely number of pods plant⁻¹, number of seeds pod⁻¹, pod weight plant⁻¹ and number of seed plant⁻¹ increased with the increase of P levels. Krishnareddy & Ahlawat (2008) investigated that dual inoculation of *Rhizobium* and VAM, significantly recorded the highest number of root nodulation, yield attributes (number of pods plant⁻¹, number of grains pod⁻¹ and grain yield plant⁻¹) and grain yield were obtained. Combined inoculation of *Rhizobium* and VAM fungi resulted in improved growth and yield. Rahman *et al.* (2008) reported that inoculation with arbuscular-mycorrhizal (AM) fungi and phosphorus fertilization on dry weights of shoot, root and seed, and uptake of N and P by the shoots of mungbean (*Vigna radiata* L.). The inoculation with *Glomus mosseae* increased dry weight of shoot and root, seed and N and P content of mungbean. Verma & Singh (2008) find out the effect of various levels of phosphorus on nitrogen fixing potential of *Rhizobium* and their response on mungbean (*Vignaradiata*). The data revealed that phosphorus and *Rhizobium* inoculation significantly increased microbiological parameters such as number of nodules, fresh weight of nodules and nitrogenase activity. Jain *et al.* (2008) reported the role of *Rhizobium* and VAM inoculation with phosphorus on mung bean (*Vignaradiata*)

cultivars PS 16 and Pusa 105 with different combinations. Dual inoculation of *Rhizobium* and VAM with phosphorus gave significantly higher yield and yield attributes in Pusa 105 as compared to PS 16. Singh (2008) reported that application of VAM exhibited significantly higher weed dry matter accumulation than the application of other biofertilizer sources. However, maximum seed and straw yield were recorded with the combined application of *Rhizobium* and VAM. Dhage (2008) reported that *Rhizobium* + PSB [phosphate solubilizing bacteria on the performance of chickpea *Rhizobium* + PSB registered the highest seed yield. Raghwendra & Kedar (2008) reported seed inoculation with *Rhizobium* markedly enhanced growth and yield of chickpea. Jain *et al.* (2008) reported Zn as Zn sulfate, Mo as sodium molybdate and B as borax with *Rhizobium* seed inoculation on two green gram cultivars, Pusa 105 and Pusa Vishal. The chlorophyll content and leaf area were found to be improved by *Rhizobium* inoculation along with P, Zn, Mo and B at in both cultivars. Pusa vishal was more responsive to these treatments compared to Pusa 105.

Singh *et al.* (2009) reported that green gram inoculated with *Rhizobium*, VAM and different nitrogen levels. The results indicate a significant improvement in nodule dry weight, rhizobial counts, root colonization, spore density, availability of N, P, K and yield of grain and straw of green gram over the control. Paola & Iulia (2009) focus on interactions among plants, mycorrhizal fungi, and bacteria, as tripartite associations. Release of active molecules, including volatiles, and physical contact among the partners seem important for the establishment of the bacteria/mycorrhizal fungus/plant network. Wang *et al.* (2009) investigated that arbuscular mycorrhizal (AM) fungi and rhizobia are two of the most important plant symbionts in natural habitats. Many leguminous plants have the ability to associate with the two microbial symbionts, which yield arbuscular mycorrhizae and root nodules. Moreover, AM fungi, rhizobia and leguminous plants are able to form a tripartite symbiosis. Beg & Singh (2009) reported that root nodule dry weight per plant, leaf area index, plant height, dry matter accumulation, branches per plant, pods per plant, seeds per pod, 1000-seed weight, seed yield, enhancement of all parameters as comparative to single inoculation of *Rhizobium* or (PSB) or chemical fertilizer application in green gram (*Vigna radiata*). Akhtar & Siddiqui (2009) reported phosphate-solubilizing microorganisms (*Glomus intraradices*, *Pseudomonas putida*, *P.*

alcaligenes, *P. aeruginosa* (Pa28), *A. awamori*) and *Rhizobium* sp. was observed on the growth, nodulation, yield of chickpea. Inoculation of *Rhizobium* sp. caused a greater increase in chickpea growth and yield than (*P. putida*, *P. aeruginosa* or *G. intraradices*). Singh & Seema (2009) reported that biofertilizer inoculations responded significantly higher in yield and nutrients uptake of crop over the control. Inoculation responded more grain yield, straw yield and nutrient uptake with treatment *Rhizobium*+PSB inoculation as compared to the control. Sammauria *et al.* (2009) reported the effect of *Rhizobium* and phosphorus solubilizing bacteria (PSB) alone and in combination on cluster bean (*Cyamopsis tetragonoloba* L. Taub.). The growth, yield attributes, and yield increased significantly due to inoculation of cluster bean with biofertilizers. Combined inoculation of *Rhizobium* and PSB was more promising from productivity and profitability point of view as compared to their sole inoculation. Vinicius *et al.* (2009) reported that dual symbiosis formed by AM fungi and *Rhizobium* can be deleterious to *Phaseolus vulgaris* growth depending on the plant variety and the symbionts involved.

Abdulla & Khaliel (2010) studied mycorrhiza, a mutualistic association between fungi and higher plants, has been documented extensively, but much less is known about the development of arbuscular mycorrhizal (AM) fungi and their effects on the growth of peanuts (*Arachis hypogaea* L.). Thenua *et al.* (2010) reported that P in the form of either SSP or DAP was better when compared with rock phosphate. The seed inoculation with phosphate solubilizing bacteria (PSB) and vesicular arbuscular mycorrhizae (VAM) followed by PSB alone recorded higher yield of chickpea. The application of rock phosphate and biofertilizer (PSB+VAM) to chickpea significantly increased. Hussain *et al.* (2010) study the influence of phosphorus fertilization and *Rhizobium* inoculation on growth and yield parameters of mungbean (*Vigna radiata*). Phosphorus application along with *Rhizobium* inoculation increased the dry weight of nodules, roots, shoots and grains significantly. Ray & Valsalakumar (2010) reported that the application of arbuscular mycorrhizal fungal and *Rhizobium* to green gram can significantly enhance its growth parameters and yield, at lesser levels than the full recommended doses of chemical fertilizers.

Asad & Vafa (2011) investigated that single and combined inoculation with plant growth-promoting rhizobacteria on nutrient uptake, growth and yield of chickpea plants.

Nodulation and nutrient concentration in shoots were significantly affected by all inoculants were statistically superior over control.

2.2 Effect of VAM and Rhizobia on nodulation and nitrogen fixation

Mayra *et al.* (2000) rhizobia bacteria form symbiotic associations with legumes species and fix-atmospheric N₂. Earlier workers have reported variable responses of nodulation to rhizobial inoculation in different leguminous crops (Hafeez *et al.*, 2000; Bloem & Law, 2001; Tarafdar & Rao, 2001; Akhtar & Siddiqui, 2009; & Thenua *et al.*, 2010) also reported positive interaction between *Rhizobium* and VAM inoculation on nodulation and nutrient uptake. Giller (2001) reported that amount of nitrogen (N₂) fixed by legume depends on plant species and cultivars, on rhizobial strains and on the environmental conditions. Tarafdar & Rao (2001) also reported positive interaction between *Rhizobium* and VAM inoculation on nodulation.

Goss *et al.* (2002) hypothesized that more rapid and extensive colonization by AMF would result in earlier formation of nodules in soybean and that this would lead to greater nitrogen (N₂) fixation by the soybean crop symbionts. Ghandour & Galal (2002) reported that nitrogen (N₂) fixation by chickpea, Giza 2 and Giza 195, were examined for their response to inoculation with either *Rhizobium leguminosarum* (Rh) or arbuscular mycorrhiza fungi (AM) and their combination. Dual inoculation with Rh and AM gave the best results of nodulation and colonization percentage comparable to those recorded with the individual inoculants.

Kumar & Chandra (2003) investigated the effects of combined inoculation of *Rhizobium* strain M-27 (a nitrogen-fixing bacterium) and *Glomus caledonium* (a vesicular arbuscular mycorrhiza or VAM) on the nodulation and grain yield of mung bean cv. Pusa Baishakhi. Combined inoculation of *Rhizobium* + VAM gave significantly more nodules and higher grain yield than single inoculation. Xavier & Germida (2003) reported synergistic effect of dual colonization of roots with AM fungi and *Rhizobium* on growth, nutrient uptake and nitrogen fixation in soybean and pea.

Kumar *et al.* (2004) determined the effects of different vesicular arbuscular mycorrhizal VAM fungi, viz., *Glomus mosseae*, *G. fasciculatum*, *G. constrictum*,

Acaulospora laevis and *Gigaspora gilmorei*, on the nodulation, nitrogenase activity and rhizosphere micro flora of chickpeas. All of the VAM fungi had no effect on the nodule number, nodule dry weight and nitrogenase activity during the crop seasons except for *Glomus mosseae* which increased nitrogenase activity. Olivera *et al.* (2004) who reported that an increase in the P supplied to host plants led to a four-fold increase in nodule mass. Therefore, the improved P nutrition resulting from AM colonization would result in improved nodulation and N-fixation, thus improving host performance.

Athar *et al.* (2005) reported in legumes that VAM fungi increased nodulation and N-fixation as a consequence of improved phosphorus nutrition.

Badr *et al.* (2006) reported that the combined effect of vesicular arbuscular mycorrhizae (VAM) and *Rhizobium* on the cold season legumes, lentil and faba bean, as well as on summer legume, soybean, were studied in soils with low indigenous VA mycorrhizal spores. Inoculation of the plant with VA mycorrhizal fungi increased the level of mycorrhizal root infection of lentil, faba bean and soybean. The inoculation with *Rhizobium* had no significant effect on VA mycorrhizal infection percent, but VA mycorrhizal inoculation increased nodulation of the three legumes. Antunes *et al.* (2006) studied generally, under controlled environment conditions, N₂ fixation in mycorrhizal soybean plants is greater than in non-mycorrhizal plants, with more nodules and greater nodule dry weight. Muhammad *et al.* (2006) reported the effect of inoculations and nitrogen levels on performance of mungbean variety NM-98. Seed and soil inoculation, and nitrogen levels were applied. Yield and yield components of mungbean crop were significantly affected by both inoculation and fertilizer application. Seed inoculation was more affective and gave better results than soil inoculation. Genevaet *al.* (2006) reported that AM fungi associated with legumes are an essential link for effective phosphorus nutrition, leading to enhanced nitrogen fixation that in turn promotes root and mycorrhizal growth.

Khan *et al.* (2008) & Mortimer *et al.* (2008) find out that shoot and root dry weight was significantly increased due to the dual inoculation than single inoculation. While the nitrogen, phosphorus and potassium uptake % was also more due to dual inoculations. Neveen *et al.* (2008) investigated that dual inoculation with both *Rhizobium* and VA mycorrhiza was a superior practice for nodules formation especially under 50%

of the recommended rate of mineral N and P fertilization, compared to either alone or uninoculated ones.

Akhtar & Siddiqui (2009) reported the number of nodules per root system was significantly higher in plants inoculated with *Rhizobium* sp. compared to plants without *Rhizobium* sp.

Abdulla & Khaliel (2010) investigated that most legumes are symbiotic with both nodule-forming *Rhizobium* spp. and AM fungi, and the tripartite relationship of host-*Rhizobium*-AM fungi is unlike either dipartite symbiosis. Nishita & Joshi (2010) that *Rhizobium* effect was studied using *Cicer arietinum* L. and controlled condition. The data reveals that, the bacterized seeds showed, 14.06% in total length over control, Increase of 10.83% in total weight over control and an increase of 9.0% on germination over control.

Bhat *et al.* (2011) studied the effect of *Rhizobium* (*Bradyrhizobium* spp. *vigna*) and vesicular arbuscular mycorrhizal fungi (*Glomus fasciculatum* and *G. mosseae*) on green gram (*Vigna radiata* L. wilzeck). Seed inoculation with *Rhizobium* significantly increased dry weight of nodules plant⁻¹, grain and straw yield, nitrogen, phosphorus and potassium uptake over the control. Similar results were observed with soil inoculation of VAM fungi.

Nazir *et al.* (2011) reported that combined inoculation of *Rhizobium* + PSB on black gram variety PU-19, slightly improved growth characters (plant height, dry matter production, number and weight of nodules per plant at maximum flowering) and the yield attributes (branches and pods per plant, seeds per pod, 1000 seed weight), than *Rhizobium* and PSB inoculated separately.

2.3 Effect of VAM and Rhizobium on dry matter and mycorrhizal dependency

Ortas *et al.* (2001) according to him mycorrhizal dependence as the degree to which a plant species is dependent on the mycorrhizal condition to produce its maximum growth at a given soil fertility. Mostly pronounced for P requirement but not for other nutrients such as Zn.

Xavier & Germida (2002) have reported a positive correlation between AM colonization of roots and total shoot dry matter production in lentil (*Lens culinaris* cv. Laird).

Pragatheswari *et al.* (2004) determined the effect of mycorrhizal inoculation effect (MIE). Grain legumes such as chickpea, cowpea, french bean, green gram and groundnut inoculated and uninoculated with a AM fungus, three distinct MIE categories have been proposed; (I) highly responsive, e.g. cowpea (ii) moderately responsive, e.g., green gram and (iii) marginally responsive, e.g. chickpea, French bean and groundnut. This result exemplifies the importance of the response of plant species to AM.

Bhat *et al.* (2005) reported the effects of biofertilizers on green gram cv. Pusa Vishal. four biofertilizer treatments (control; *Rhizobium* inoculation; phosphorus-solubilizing bacteria inoculation; and vesicular arbuscular mycorrhiza (VAM) inoculation). All the biofertilizers showed stover yield significantly higher than that of the control based on dry matter accumulation. Tufenkci *et al.* (2005) reported that inoculation with arbuscular mycorrhizal fungi, P and N fertilizer application on the yield and nutrient content of chickpea cv. Aziziye-94. Data were recorded for plant height, fresh weight and dry weight.

Badr *et al.* (2006) reported that dual inoculation with both rhizobia and mycorrhizae induced more significant increases in plant dry weight, N and P content of lentil and faba bean as well as seed yield of soybean than inoculation with either VA mycorrhizae or *Rhizobium* alone.

Gitasree (2007) reported that inoculation of chickpea (*Cicerarietinum*L.) combined inoculation with PGPR and an effective strain of *Rhizobium* sp. of *Cicerarietinum*L. enhanced nodulation, plant dry weight of the crop over uninoculated control and also to *Rhizobium* alone. Goud & Reddy (2007) reported that the effect of *Rhizobium* inoculation on the growth and yield of summer green gram (*Phaseolus radiatus* [*Vigna radiata*]) cv. *Rhizobiainoculation* resulted in more dry matter accumulation and leaf area index over uninoculated treatment.

Khan *et al.* (2008) find out that shoot and root dry weight was significantly increased due to the dual inoculation than single inoculation. Singh (2008) reported that application of VAM exhibited significantly higher dry matter accumulation than the application of other biofertilizer sources.

Sara *et al.* (2009) reported the species *M. lacerata*, *M. luisana*, *M. polyantha* and *M. texana* var. *filipes* had a high mycorrhizal dependency index indicating that plant growth was strongly increased by arbuscular mycorrhiza activity.

Abdulla & Khaliel (2010) studied the growth and dry matter of the peanut plants, AM fungi become beneficial symbiotic microorganisms that increased the growth and plant biomass of mycorrhizal host plants. Shehata *et al.* (2010) stated that effect of different fertilization treatments on leaf fresh and dry weight, the combination of full dose of N and soil inoculation with biofertilizer recorded the highest values. In addition, no significant differences were detected among the treatments of inoculation with biofertilizer either with 45 and 30 kg N/ fed or the sole application of N. Meanwhile, the inoculation with biofertilizer solely possessed the lowest significant effect in leaf dry weight compared to control and other treatments.

Nazir *et al.* (2011) reported that combined inoculation of *Rhizobium* + PSB slightly improved growth characters, plant height and dry matter production. Hence, the microhabitats occupied by bacteria are determined based on their feeding properties, their kind of symbiosis, soil and climate properties and their host specifications. Combined inoculation on black gram improved growth characters (plant height, dry matter production, number and weight of nodules per plant at maximum flowering) and the yield attributes (branches and pods per plant), than *Rhizobium* and PSB inoculated separately.

2.4 Host growth stages, VAM root colonization and VAMF spores

Satpal & Kapoor (2000) study the effects of vesicular arbuscular mycorrhizal (VAM) fungi, with and without Mussoorie rock phosphate (MRP) in P-deficient soil with mungbean (*Vigna radiata*). The MRP stimulated root colonization, the plant biomass and nutrient uptake. But the highest plant biomass, N and P uptake was observed on mung bean inoculated with *Glomus fasciculatum* in presence of MRP.

Ortas *et al.* (2001) find out mycorrhizae species to be different in root colonization and dependence ratio in a low-fertility soil with increased P and Zn application.

Niranjan *et al.* (2002) find out that highest value of mycorrhizal root colonization was found in seedlings inoculated with *Glomus mosseae*. Lukiwat & Simanungkalit

(2002) reported that root colonization and spores number of VAM were significantly higher with dual inoculation than others treatment. Hart & Reader (2002) reported that AMF families vary widely in the pattern of root colonization and life strategy. Klironomos & Hart (2002) reported before root penetration, some rely on their large spores and are slow root colonizers, as compared to others that use delicate and diffuse hyphae as their most infective propagule. Species belonging to the *Gigasporaceae* fit the former strategy, whereas *Glomaceae* are associated with the latter.

Oehl *et al.* (2003) studied that moreover, there is indication that *Glomus* species have become more abundant in agro ecosystems.

Pragatheswari *et al.* (2004) reported that inoculation of soil with *Glomus mosseae* markedly increased the level of VAM colonization in roots of all plant species, but the extent of VAM colonization in roots decreased at soil solution P level increased. VAM colonization in tropical grain legumes varied with plant species as well as different soil solution phosphorus levels. Kumaret *al.* (2004) reported that mycorrhizal inoculation resulted in better colonization of roots with VAM and caused reduction in the uptake of nutrients (N, P, K and Zn) in chickpea plants. Scheublin *et al.* (2004) showed that root nodules contained AMF communities that were different from those in the legume roots, which strongly supports the hypothesis that AMF functional diversity is important in the tripartite symbiosis.

Duponnois *et al.* (2005) reported that AM fungi colonize the root cortex of plants and develop an extrametrical hyphal network that can absorb from the soil. The structure and functionalities of these AM associated microbial communities differ from those of the rhizosphere. Olah *et al.* (2005) & Gutjahr *et al.* (2009) reported AM fungal colonization influences root architecture of the host plant in most studies by causing a more profusely branched root system.

Antunes *et al.* (2006) studied the variation in life strategies among the AMF may be linked to host–symbiotic compatibility phenomena which represents an important aspect of mycorrhizal soil ecology, particularly regarding the interaction with *B.japonicum* and soybean. Colonization of roots by AM fungi has been shown to improve growth and productivity of several field crops (Cavagnaro *et al.*, 2006; Pasqualini *et al.*, 2007) by increasing nutrient element uptake (Karaki, 2006). These fungi are also known to

enhance crop growth and yield through enhanced tolerance to various biotic (Khaosaad *et al.*, 2007) and abiotic stress factors (Garni, 2006 & Takeda *et al.*, 2007) and improving physical, chemical and biological properties of soil (Rillig & Mumme, 2006; Cardoso & Kuyper, 2006). Scheublin *et al.* (2006) reported that AMF colonization of the nodules ranged from 5% to 74% and depended on plant species, AMF identity and nutrient availability.

Valsalakumaret *al.* (2007) reported that correlations of spore count and percentage colonization for all the AM fungi on the crop in the field, along with soil parameters like pH, N, P, and K were studied. Significant negative correlation was obtained between percentage colonization and P. The pH and N were positively correlated with K. The study indicates involvement of factors other than soil nutrients in the distribution and sporulation of AM fungi. Antunes *et al.* (2007) reported that plants colonized by arbuscular mycorrhizal (AM) fungi have been shown to respond positively to the application of insoluble forms of inorganic phosphorus (P) such as rock phosphates (RPs) AM fungi can solubilize P from RPs and transfer it to plant roots. Valsalakumaret *al.* (2007) reported that rhizosphere soil samples were analyzed for AM fungal spores. *Glomus mosseae*, *Glomus microcarpum*, *Gigaspora margarita*, and *Scutellospora* sp. were identified as the AM fungi associated with green gram. *Glomus mosseae* was the most frequent AM fungal associate identified in 81%, *G. microcarpum* and *G. margarita* in 24% each, and *Scutellospora* sp. in 5% of the soils studied. The range of distribution varied from a single species of AM fungus to three species belonging to two genera in one sample.

Javaid & Riaz (2008) reported a significant positive correlation of root and shoot biomasses with different parameters of arbuscular and vesicular colonization in maize.

Powell *et al.* (2009) reported that majority of variation in root colonization by AM fungi is explained by the divergence of the two most species-rich fungal clades: the extensively colonizing *Glomerales* and the poorly colonizing *Diversisporales*. Sabannavar & Lakshman (2009) reported that Phosphate solubilizing bacteria behaved as mycorrhiza helper bacteria promoting higher colonization rate and spore number of AMF which helps in solubilization of the mineral phosphate

Murat *et al.* (2011) reported that Arbuscular mycorrhizal fungus (AMF) inoculation, alone or in combination with rhizobial inoculation, resulting in large increases in yield, root colonization and phosphorus content of the seed and shoot.

2.5 Mineral composition

Gavito *et al.* (2000) & Mayra *et al.* (2000) investigated the effect atmospheric CO₂ on biomass partitions and nutrient uptake of mycorrhizal and non-mycorrhizal pea plant (*Pisum sativum* L.). George (2000) reported that the colonization of plant roots by arbuscular mycorrhiza (AM) fungi can greatly affect the plant uptake of mineral nutrients. Many mycorrhizal fungi can transport nitrogen, phosphorus, zinc, and copper to the host plant.

Bressan *et al.* (2001) reported that the AM- fungi also increases the uptake of K, and concentration of K has been found more in mycorrhizal than non-mycorrhizal plants. Subba Roa (2001) reported that mycorrhiza have been widely accepted as bio-fertilizers, However these supply only major nutrients but a host of microorganism that can transform micronutrients are there in soil that can be used as bio-fertilizers to supply micronutrients like zinc, iron, copper etc.

Habte & Osorio (2002) investigated that AM fungi absorb P, K, Ca, S, Fe, Mn, Cu, and Zn from the soil and then translocate these nutrient to the plants. John (2002) reported that both the fungal and rhizobial microsymbionts improve mineral nutrition of the host plant.

Zaidi *et al.* (2003) reported that nutrient uptake was significantly enhanced as a result of inoculation with *Rhizobium* sp. and phosphate solubilizing microorganisms (PSM). Nutrient uptake was further augmented by the addition of AM fungus, *Glomus fasciculatum* in the combined inoculation treatment with *Rhizobium* sp. Kalipada & Singh (2003) reported that the inoculation of phosphate solubilizing bacteria (PSB) +vesicular arbuscular mycorrhiza (VAM) recorded high nutrient uptake over PSB and VAM individual applications. The nutrient uptake also increased with increasing levels of P.

Gupta (2004) reported that dual inoculation of gram with *Rhizobium* and phosphorus-solubilizing bacteria either as seed or as soil inoculation significantly

increased nitrogen uptake (30.5-37.5%), phosphorus uptake (1.9-2.3 times), soil rhizosphere *Rhizobium* (10.6-13.8 times) as well as phosphorus-solubilizing bacteria population (23-31 times) over the control. Rohyadi *et al.* (2004) investigated that there were differential effects of the two fungi on uptake of mineral elements. Plants inoculated with *Gigaspora margarita* took up a range of elements, including P and Zn as well as Al, to a much greater extent than those inoculated with *Glomus etunicatum*, regardless of medium pH. Sharma (2004) find out that mineral nutrient acquisition from soil is considered to be the primary function of mycorrhizas. The demand for a particular mineral nutrient depends on plant internal requirements, while the supply of that nutrient primarily depends on its availability and mobility in soils.

Azmat *et al.* (2005) studied the effect of (Cadmium) Cd metal on essential mineral ions nutrients of *Vigna radiata* (bean) plants was examined. Results were explained in relation with soil microorganism and acquisition of mineral nutrients like Na, K, Ca, Mg, Mn, PO₄ and Fe. Analysis of roots showed that *Rhizobium* species were affected by heavy metal Cd which results in the inhibition of nodulation of leguminous plant and decreases in the acquisition of mineral ions concentration at all concentration of cadmium. Tufenkci *et al.* (2005) reported that inoculation with arbuscular mycorrhizal fungi application on the yield and nutrient content of chickpea cv. Aziziye-94. AMF inoculation significantly increases the contents of P, K, Ca and Zn. Kytöviita (2005) reported that mycorrhizal symbiosis generally improves nutrient and water acquisition of the host plant.

Khan *et al.* (2006) find out that mineral ion concentrations in broadleaf plants including leguminous plants are more than those in grasses and other forages. Gonzalez *et al.* (2006) reported that mineral ion concentration decreases with increase in age both in the case of legumes and grasses.

Neveen *et al.* (2008) reported that fungal infection and rhizobial inoculation either alone or in combination with 50% or 75% of the recommended doses of N and/or P fertilizers increased nodules formation, plant growth and yield as well as the concentration of N, P, K, Fe, Zn, Mn, Cu, protein, and total carbohydrate on both cultivars as compared to uninoculated plants. Neveen *et al.* (2008) reported that dual inoculation was of significant importance, resulted in increase plant productivity, which

could be attributed to enhancing mineral uptake, producing phytohormones and altering the microbial balance. Khan *et al.* (2008) reported that nitrogen, phosphorus and potassium uptake % was also more due to dual inoculations.

Fatma *et al.* (2009) reported that common bean has the potential to establish symbiosis with arbuscular mycorrhizal fungi (AMF) that improves the uptake of low mobile nutrients such as phosphorus, from the soil.

Smith *et al.* (2010) investigated AM fungi may influence soil structure, carbon deposition in soil and interactions with the soil microbial and animal populations, as well as plant-plant competition. These interlinked outcomes of AM symbioses go well beyond effects in increasing nutrient uptake. Singh & Singh (2010) reported that the sulfur (S) and cobalt (Co) application of fertilizer at recommended dose significantly enhanced micronutrient uptake as compared to application of *Rhizobium* inoculant, maximum nutrient content of Fe 318.33, 357.33 ppm; Zn 36.00, 56.33 ppm; Mn 98.0, 108.0 ppm; and Cu 25.33, 18.0 ppm in grain. Sheraz *et al.* (2010) reported that AM-fungi also increases the uptake and efficiency of micronutrients like Zn, Cu, Fe etc. by secreting the enzymes, organic acids which makes fixed macro and micronutrients mobile and as such are available for the plant.

Bhat *et al.* (2011) studied the effect of *Rhizobium* (*Bradyrhizobium* spp. *vigna*) and vesicular arbuscular mycorrhizal fungi (*Glomus fasciculatum* and *G. mosseae*) on green gram (*Vigna radiata* L. wilzeck) significantly increased nitrogen, phosphorus and potassium uptake over the control. Similar results were observed with soil inoculation of VAM fungi. Murthy (2011) reported that mature seed samples were analyzed for mineral composition. The mature seeds were rich in sodium, phosphorus, calcium, zinc, manganese and iron.

2.6 Nutritional composition

The salt-soluble protein fraction of pea isolate was reported by Chakraborty, Sosulski, & Bose (1979) to contain 70.2% of the total flour protein and consisted of 2S (25%), 7S (43%), 11S (28%) and 15S (4%) proteins. Gueguen & Barbot (1988) reported that protein content of pea varieties range from 23.1% to 30.9% (Nx5.6) with albumin and globulin representing 15–25% and 50–60% of the total protein, respectively. Rao *et al.* (1989) reported that pea seed albumins to account for roughly 15–40% of the total

proteins in the cotyledon. Swanson (1990) reported that with the remaining proteins being largely globulins (legumins and vicilins). Gupta & Dhillon (1993a) reported that crude protein contents of whole seed, defatted seed, cotyledon flour, and defatted cotyledon flour of lentil were reported as 25.9%, 27.8%, 29.1% and 31.1%, respectively. Gupta & Dhillon (1993b) reported that albumins, legumins, vicilins, glutelins and prolamins were 16.8%, 44.8%, 4.2%, 11.2% and 3.5% of the total proteins, respectively.

Silva & Lourenço (2001) studied that chickpea globulins were found to represent the largest fraction (41.79%) of the total protein, followed by albumin (16.18%), glutelin (9.99%), and prolamin (0.48%). Singh & Pareek (2003) reported that biofertilizers on the performance of mung bean. *Rhizobium* + PSB resulted in the highest N contents of grain (4.156%), grain yield (8.57 quintal/ha), and seed protein content (26.152%). Gupta (2004) reported that dual inoculation in gram with *Rhizobium* and phosphorus-solubilizing bacteria either as seed or as soil inoculation significantly increased protein content in seeds (4.9-5.7%). O'Kane *et al.* (2004) found legumin:vicilin ratios varying from 0.2 to 1.7 compared to the globulin, pea albumins contain more of the essential amino acids tryptophan, lysine, threonine, cysteine and methionine. Sher *et al.* (2004) reported that inoculation with *Rhizobium* + PSB resulted in higher seed and straw yields, protein content, compared to no inoculation and single inoculation with *Rhizobium* or PSB.

Harrison (2005) reported that this mutualistic association provides the fungus with relatively constant and direct access to carbohydrates, such as glucose and sucrose supplied by the plant. Jat & Ahlawat (2006) reported that seed inoculation of chickpea with *Rhizobium*+PSB (phosphate solubilizing bacteria) increased grain yield and protein content of chickpea, over no inoculation and inoculation with *Rhizobium* alone. Muhammad *et al.* (2006) reported that chick pea seeds are more palatable, nutritive, digestible and non-flatulent than other pulses grown in country. Its seeds contain 24.2% protein, 1.3% fat and 61.4% carbohydrates, calcium and phosphorous are measured as 118 mg and 340 mg per 100 g of seeds, respectively. Zaidi & Saghir (2006) reported that composite application of *Mesorhizobium ciceri* with *serratia* and arbuscular mycorrhizal fungus *Glomus fasciculatum* had maximum positive effect on chickpea protein content in seeds varied between 18 and 24% in inoculated.

Ali & Kumar (2006), Akhtar & Siddiqui (2009) reported that amongst the leguminous crops, chick-pea (*Cicer arietinum* L.) occupies an important position due to its nutritive values (17-25% protein) in large vegetarian population of the country. Sheteawi & Tawfik (2007) reported that commonly slightly higher amounts of total carbohydrates, lipid and total crude protein contents were obtained in seeds of plants irrigated every 5 d than those of 10 d drying cycle while they were more or less comparable for the biofertilized and nonfertilized plants. Shuheet *et al.* (2008) reported that rhizobia form a very interesting symbiotic relationship with leguminous plants. This relationship has attracted the attention of biologists all over the world due to the great impact of legumes for sustaining nutritional demands to humans and animals. Dhage (2008) reported that *Rhizobium* + PSB [phosphate solubilizing bacteria] and RFR + *Rhizobium* + PSB + on the performance of chickpea. *Rhizobium* + PSB registered the highest seed yield, protein content (19.88%) and protein yield (3.75 quintal/ha. Neveen *et al.* (2008) reported that fungal infection and rhizobial inoculation either alone or in combination with 50% or 77% of the recommended doses of N and/or P fertilizers increased protein, and total carbohydrate on both cultivars as compared to uninoculated plants. Erdal *et al.* (2008) reported that single, dual, and triple inoculations with *Rhizobium*, significantly increased total biomass yield, and seed protein content compared with the control treatment, equal to or higher than N, P, and NP treatments.

Sheraz *et al.* (2010) reported that mycorrhizal associations (VAM) in alleviating toxicity, increasing N, P and micronutrient uptake, maintaining soil structure by the production specific protein called "Glomulin". Murthy (2011) investigated that mature seed samples were analyzed for proximate composition, the seed samples contained higher amount of crude protein, crude fat and ash. The calorific value of 100g dry matter of seed material was 1783.92 kj/100 Dm. The fatty acid profiles revealed that the seed lipids contained higher concentrations of palmitic and linoleic acids.

Aims and Objectives

This study will be carried out to achieve the following objectives

1. To establish the mycorrhizal and rhizobial status of some varieties of the selected plants (Green mung bean, Lentil, Pea, Burgundy and Desmodium).
2. To study the varietal response of the legumes to VAM, Rhizobial and Rock phosphate and their combine inoculation.
3. To find out the M.D (Mycorrhizal dependency) values of chosen legumes.
4. To assess the efficacy of *Rhizobium*, mycorrhizal and Rock phosphate inoculation of a selected group of legumes in net house.
5. Role of VA Mycorrhizal in the Phosphorus nutrition of economic leguminous crops.

MATERIALS AND METHODS

The present research work divided into two parts.

- 3.1 Lab. Work
- 3.2 Field Work

Lab. Work

The laboratory work was done in following two steps.

- 3.1.1 Assessment of roots
- 3.1.2 Extraction of spores.

Assessment of Roots

Collection and preservation of roots

Roots of investigated plants were cut, collected, preserved in the Formalin Acetic acid (F.A.A) solution.

Preparation of preservative

70% alcohol was used as preservative. 70% alcohol was prepared by taking 70ml of alcohol and 30ml of distilled water.

Preservation

Plant roots were thoroughly washed with tap water to remove attached soil particles. They were cut into small segments then preserved in glass bottles containing 70% alcohol. The bottles were labeled and kept at room temperature in the laboratory.

Preparation of KOH solution (10%)

KOH solution was prepared by mixing 10gm of KOH in 90ml of distilled water. The solution was stirred thoroughly and kept at ordinary room temperature.

Preparation of acid fuchsin stain

To prepare acid fuchsin stain 0.025gm of acid fuchsin was dissolved in 220ml of lactic acid and then mixed with 10ml of distilled water and 16ml of glycerin. The solution was stirred well and used for staining. Two procedures were used for staining.

Two Procedures were followed for assessment of roots as follow:

Phillips & Hayman (1970) Procedure

The staining procedure given by Phillips & Hayman (1970) was used for staining fungal structures with some modifications for non-pigmented roots.

- A. Root preserved in 70% alcohol were thoroughly washed with tap water and then heated in 10% KOH for 5 – 10 minutes to remove the host cytoplasm and most of the nuclei .
- B. The roots were further rinsed with tap water and dried on filter paper.
- C. Finally they were stained by heating in 0.025% acid fuchsin for 3 – 5 minutes.

Kormanik (1982) Procedure

Following method used for stained roots

- A . Material fixed in 70% alcohol was washed with tap water and then heated in 10% KOH for 10 –15 minutes.
- B . The pigmented portions were kept in alkaline H_2O_2 for 10 –15 minutes until it was completely bleached. H_2O_2 was prepared by adding 3ml NH_2OH to 30ml of 10% H_2O_2 and 5.767ml of distilled water.
- C. The bleached parts were then rinsed off thoroughly with tap water to remove H_2O_2 .
- D. Finally materials were soaked in 1% HCl for 1– 2 minutes.
- E. Later the solution was thrown away and the roots were not rinsed with tap water to keep acidic effect for proper staining .
- F. The roots were stained by heating in 0.025% acid fuchsin for 2 –3 minutes .

Assessment of root colonization

The procedure of Giovannetti & Mosse (1980) was followed. It is $\pm$ slide method. Fifty segments of roots of individual plant each approximately 1 cm long were randomly selected for microscopic study. Morphology of VAM entophyte was studied and expressed in percentage (%). The infection percentage was calculated by using the following formula:

$$\% \text{ age mycorrhizal infection} = \frac{\text{No. of infected segments}}{\text{Total No. of segments studied}} \times 100$$

Microphotographs of the best selected slides were taken.

3.1.2 Extraction of Spores

Rhizospheric soil samples were collected from (Green mung bean, Lentil, Pea, Burgundy and Desmodium) plants at different stages of host growth vegetative, flowering and fruiting stages. A 100 gm sample of rhizospheric soil was taken from each of the test plants. Table 1. Seven treatments x 4 varieties of Lentil, 3 varieties of green mungbean, 1 variety of pea, 1 variety of Desmodium, 1 variety of Burgundy x 5 replicates at a depth 15-20 cm. Wet sieving and decanting technique of Gerdemann & Nicolson (1963) was used to extract the spores from collected soil sample. Hundred gm soils suspended in water and agitated vigorously to detach soil debris and aggregate in order to get uniform mixture solution passed through 2mm sieve to screen out large debris and wash the residue several times. Small amount of the residue was put into petri dishes for studying the spores. The soil suspension was agitated and passed successively through the sieves numbers 30, 50, 90, 106, and 250 μm size. The number of sieves can be reduced or increased according to soil texture or purpose of extraction (Dalpe, 1993). The residue was collected from each sieve on the filter papers in petri dishes and examined under microscope separately.

Mounting of spores

Spores were picked up with the help of needle and placed on a slide in a drop of Canada balsam.

Calculation of density of spores

Density is defined as the mean number of spores per 100 gm soil. It was calculated by standard method following Stahl & Christensen (1982).

Identification of spores

The spores were micro photographed at various magnifications (4x, 10x). They were identified with the help of keys following Hall & Fish (1979), Trappe (1982) and Schenck & Perez (1990).

3.2 Field Work

Experimental site

Winter in Peshawar starts from mid November to the end of March. Summer months are May to September. The mean maximum temperature in summer is over 40 °C (104 °F) and the mean minimum temperature is 25 °C (77 °F). The mean minimum temperature during winter is 4 °C (39 °F) and maximum is 18.35 °C (65.03 °F).

Biological materials, time schedule and cultural practice

Detail about biological material, time schedule and cultural practice are mentioned in Table 1.

Species Selection

Seeds	Varieties	Source
Summer crops <i>Vigna radiata</i> L. Wilczek Cv. (Green mungbean)	NIAB-98	NIAB Faisalabad
	NIAB-92	
	NIAB.2006	
<i>Macroptilium bracteatum</i> (Burgundy Bean)	-----	Department of Agronomy Agriculture university Peshawar
<i>Desmodium adscendens</i>	-----	Department of Agronomy Agriculture university Peshawar
Winter crops <i>Lens culinaris</i> Medic. (Lentil)	NARC.2008-2	NARC Islamabad
	NARC.2008-3	
	NARC.2008-4	
	NARC.2002	
<i>Pisum sativum</i> L. (Pea)	-----	Department of Agronomy Agriculture university Peshawar

Experimental Layout

Two field experiments were carried out at the Experimental Net House of Department of Botany University of Peshawar Pakistan during the successive seasons of summer and winter (2009 and 2010) to evaluate the influence of seed inoculation with *Rhizobium* and/or soil inoculation with the vesicular arbuscular mycorrhizal (VAM) and different levels RP fertilization on the growth, yield, yield components, elemental and nutritional value of three mungbean (*Vigna radiata*), four Lentil (*Lens culinaris*), Pea (*Pisum sativum*), Desmodium (*Desmodium adscendens*) and Burgundy (*Macroptilum bracteatum*).

Rhizospheric soil from wheat and maize field having high spores number of different AMF i-e *Glomus fasciculatum*, *G. mosseae* and *G. aggregatum* and roots of wheat and maize infected with Arbuscular mycorrhiza were used as rhizobase inoculum. Roots were cut into 1cm pieces. These root pieces along with soil base inoculum (rhizospheric soil) were spread uniformly in layers at a depth of 3cm and 6cm before sowing. Inoculum for each pot consisted of 180 gm of mycorrhizal infected roots and adhering soil. The spore density was found to be 290 spores per 100g of soil.

Rhizobial Inoculum

Seed inoculation with rhizobium was done by using effective *Rhizobium leguminosarum* bv. *viceae* strain D 293 and *Rhizobium* strain TAL-169 (*Rhizobium* spp.) which were obtained from Land Resource Research Institution, NARC Islamabad. The mungbean, lentil, desmodium, burgundy and pea seeds were coated with gum. Thereafter the inoculum was mixed with gum acacia and coated and were shade dried.

Soil used

Soil used during the experiment was collected from the University of Peshawar. The soil was air-dried, sieved (4 mm) and analyzed at the Department of Soil and Environmental Sciences Agriculture University Peshawar. The soil had 6.65% organic matter, 0.044% nitrogen, 1.13% phosphorus and (7.30) pH. After sieving, soil finely ground and mixed with sand in ratio of 2:1 (soil/sand) resulting in the sandy loam textured soil. Rhizobia and

AMF inoculum in the soil: sand mixed. And 10 kg/pot soil was used. All pots of equal diameter (70.6cm) and length (21cm) were filled with this processed soil.

Experimental design, treatments and replications

The experiment was laid out in a random block design (CRD) with seven treatments, each treatment was replicated five times with in each pot {Seven treatments x 4 varieties of Lentil, 3-varieties of green mungbean, 1-variety of pea, 1-variety of Desmodium, 1-variety of Burgundy x 5 replicates}. Each treatment includes 5 pots, and 10 –20 seeds were sown in each pot. Seeds were placed at 5-cm depth from the soil surface. For the AMF treatments, the appropriate AMF inoculum was placed in soil over which seeds were planted. For the *Rhizobia* treatments, *Rhizobia* strains was added over seeds, and for the AMF+*Rhizobia* treatments, AMF inoculum was placed in soil over which seeds were planted and *Rhizobium* culture was added. RP Fertilizers were applied in each pot according to treatments as basal dose. These plants were grown in net house during summer and winter seasons. The control treatments were not inoculated with AM fungi, *Rhizobia* or rock phosphate.

There were following treatments (each with five replication) in a Complete Randomized Design (CRD).

1. Control (Un inoculated)
2. Inoculation with VAM fungus alone
3. Inoculation with *Rhizobium* alone
4. Inoculation with *Rhizobium* + VAM (Dual inoculation)
5. application with Rock phosphate alone
6. Inoculation with Rock phosphate +VAM (Dual inoculation)

Pots were randomly placed and maintained under natural condition in the net house. Probabilities of significance were used to test for significance among treatments, varieties and interactions.

Table 1. Biological materials, time schedule and cultural practice.

Biological material	Time schedule and cultural practice					
	Varieties	Source	Time of sowing	Watering	Thinning	Harvesting
Summer crops <i>Vigna radiata</i> L. Wilczek Cv.(Green mungbean)	NIAB-98	NIAB Faisalabad	27.7.2010	The plants were watered regularly. Amount of water was increased at the stage of fruit riping.	The weak plants were removed and only five healthy plants were left in each pot allowed to grow for agronomic studies.	9-10.2010
	NIAB-92					
	NIAB.2006					
<i>Macroptilium bracteatum</i> (Burgundy Bean)	-----	Department of Agronomy Agriculture university Peshawar	22.7.2010			12.10.2010
<i>Desmodium adscendens</i>	-----	Department of Agronomy Agriculture university Peshawar	22.7.2010			12.10.2010
Winter crops <i>Lens culinaris</i> Medic. (Lentil)	NARC.2008-2	NARC Islamabad	18.10.2010			26.3.2010
	NARC.2008-3					
	NARC.2008-4					
	NARC.2002					
<i>Pisum sativum</i> L. (Pea)	-----	Department of Agronomy Agriculture university Peshawar	13.10.2010			20.3.2010

Evaluation of growth Parameters

The following parameters were recorded.

a. Agronomic and yield parameters

1. Plant height
2. Number of Leaves/plant
3. Number of flowers / plant
4. Number of pods/plant
5. Length of pod
6. Number of seeds/pod

b. Nutrient uptake

1. Micro- nutrients (Zn, Fe, Mn, Cu)
2. Macro-nutrients (K, Na, Mg)

Plant harvest and parameters

All Plants were harvested at fruiting stage (Table.1). The above ground plant material was separated, dried (65°C; 48 h) and weighed. Seeds were separated from the dried shoot material and weighed. Shoot and seed material of harvested plants were digested using an H₂SO₄–H₂O₂ mixture, determined (Thomas *et al.*, 1967). The percentage of AMF-colonized root length was determined using a modified gridline intersect method of Giovannetti & Mosse (1980). Wet sieving and decanting technique of Gerdemann & Nicolson (1963) was used to extract the spores from each collected soil sample.

Mycorrhizal dependency (MD)

Mycorrhizal dependency (MD) value of selected legumes was calculated by the formula given by Plenchette *et al.* (1983).

$$\text{MD (\%)} = \frac{(\text{DW}_{+M} - \text{DW}_{-M}) \times 100}{\text{DW}_{+M}}$$

3.3 Proximate Analysis

Kjeldhal-N was determined and protein content was calculated by multiplying nitrogen by the factor 6.25 (A.O.A.C. 2000). Percent moisture, crude fat, ash and crude fiber contents were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006).

Dry matter and Ash

For the estimation of dry matter (DM) and ash, about 2g samples were taken in clean and pre-weighed crucibles in duplicate. The crucibles were then placed in laboratory oven for 18h at 100°C. After drying in an oven the samples were cooled in a dessicator for 30 minutes and reweighed. The Dry matter (DM %) was determined by using the following formula.

$$\text{DM (\%)} = \frac{(C-A) \times 100}{(B-A)}$$

A = weight of empty crucible

B = weight of crucible + sample (pre drying)

C = weight of crucible + sample (post drying).

The samples were incinerated in a muffle furnace at 550°C for 6h to estimate its ash content. After incineration the samples were cooled again in a dessicator and were re-weighed. Dry matter and Ash contents were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006). Ash was calculated as under:

$$\text{Ash (\%)} = \frac{(D-A) \times 100}{(C-A)}$$

A = weight of empty crucible

C = weight of crucible + sample (post drying)

D = weight of crucible + ash

MoistureContents

Weight accurately oneto two grams of sample in a clean weighed Petri-dish (W_1), place the Petri-dish partially covered with lid in the oven at 105 ° C, for 4-6 hours, until constant weight in obtained. Then removed the petridish covered with the lid, and place it in desiccators for 30 min in order to cool it. After cooling weigh the dish (W_2).Moisturecontents were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006).Percent moisture may be calculated as follow:

$$\% \text{ Moisture} = \frac{(W_1 - W_2) \times 100}{\text{Wt of the sample}}$$

Crude Protein (CP)

In this method samples were digested with concentrated sulphuric acid (H_2SO_4) and were followed by distillation and titration. Samples (about 0.3 gm) in duplicate were taken in the Tecator digestion tubes and were added with 5 gm of catalyst (Potassium Sulphate 93%, Copper sulphate 7%) and 10 ml concentrated sulfuric acid. Acetanilide (0.1 gm) was processed as standard for recovery of nitrogen. The digestion tubes were heated in Tecator digestion block. The tubes were then allowed to cool at room temperature.

About 15 ml distill water was added with the tubes containing digested samples. After dispensing required amount of sodium hydroxide (NaOH) solution (40% W/V) in the tubes to alkaline the sample and the contents were distilled for about seven minutes. The resulting ammonia was collected in conical flask containing 10 ml boric acid (2%) and 3-4 drops of methylene red indicator.

The titration of distillate was carried out with 0.5 N sulfuric acid solutions. To determine the blank values duplicate tubes containing 15 ml distilled water and 5 ml NaOH were also processed for distillation and titration.Crude Protein in the representative sample of feed and was determined with Kjeldhal Method (A.O.A.C. (2000). The percentage of nitrogen was calculated as under:

$$\text{Percent Crude Protein} = \frac{(\text{ml } \text{H}_2\text{SO}_4 - \text{blank}) \times \text{Nitrogen} \times (6.25 \times 14.01)}{(\text{Sample weight} \times 100)}$$

Crude fat (Ether extract)

The instrument used for the extraction of crude fat is Soxhelt's apparatus in this method; first weigh 2-4 gram of extraction thimble. The thimble is plugged with absorbent cotton wool the thimble is placed in extraction chamber. A previously clean and dried 250 ml round bottom flask, is weighed, then fill up 1/3 of this flask with solvent and connect it with the extraction tube. Put the sample fasten in filter paper. Then set the whole apparatus and turn on the flow of tap water and burner. Continue the extraction for 5-6 hrs; siphoning will occur after 5-6 min at the condensation rate of 3-4 drops per second. After completion of the process; remove the thimble from the extractor and heat the flask so that all the solvent can be collected for future. Then the flask is dried at 105 °C. Finally, it is cooled and weighed again. Crude fat of samples were determined by AOAC (2000) method the percentage of EE was calculated as under:

$$\% \text{ EE (DM)} = \frac{(\text{Weight of ether extract})}{(\text{Sample weight})} \times 100$$

Crude fiber by Fibertec(CF)

Weigh and transfer quantitatively an exact quantity (about 1.0 gram = W_o) of a sample into a clean filter crucible. Place the crucible in the crucible stand. Add a few drops of octanol to prevent foaming and heat to boiling for 30 min. Filter and wash three times with hot water from spray device (30 ml of water) and such as dry as possible. Add few drops of octanol and boil as above for another period of 30 mints. Crude fiber contents were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006).

$$\% \text{ CF (sample)} = \frac{(\text{crucible wt.} + \text{dried residue}) - (\text{crucible wt.} + \text{ash residue})}{(\text{Crucible wt.} + \text{sample}) - \text{empty crucible weight}} \times 100$$

$$\% \text{ Crude fibers} = \frac{(W_1 - W_2) \times 100}{(W_o)}$$

Total Carbohydrates

Total carbohydrates were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006). Total Carbohydrate were calculated after Galyean (1985) as follows:

Total Carbohydrates = $(100 - \% \text{ moisture} - (\% \text{ Ash} + \% \text{ fibers} + \% \text{ fats} + \% \text{ protein}))$.

3.4 Mineral Constituents

An acid digest was prepared by oxidizing each sub-sample with a nitric/perchloric acid (2:1) mixture. Aliquots were used to estimate Na and K by flame photometry, and Ca, Mg, Mn, Fe, Cu and Zn by atomic absorption spectrophotometry (A.O.A.C., 1990). Each sample was analyzed thrice and the mean data are reported. The elemental analysis was done for all tested plants at CRL. Physics dept University of Peshawar, using flame atomic absorption spectroscopy by Perkin Elmer A Analysts 700 device.

Potassium

Potassium contents (K) were determined by atomic absorption spectrophotometer (PYE UNICAM Spa) in the flame emission mode at 766.5 nm using a fuel lean air/acetylene flame. Computer programmed Spa on the attached computer was operated and key run commenced the sample feeding for estimation of potassium. Standard potassium solutions were prepared and run through spectrophotometer and standard curve was plotted with different concentrations of potassium. The samples were diluted with 250 ml of Lithium sulphate solution and sample solutions were run to determine the potassium contents in samples from the respective standard curve.

Sample preparation

Plant samples were washed with water and oven dried at 80°C for 2 days and then subjected to grinding for powder formation by electric grinder. 0.5 gram powder of each plant sample was dissolved in 10 ml of nitric acid for 24 h and then heated by an electric heater until the reddish brown fumes with complete white color.

Atomic absorption spectrophotometer

Macro (Ca, Mg, K) and micro (Mn, Cu, Fe and Zn) elements were determined using flame atomic absorption spectroscopy by Perkin Elmer A Analyst 700 device at CRL. Physics Department University of Peshawar. All reagents were of analytical reagent grade unless otherwise stated. Double deionized water (Milli-Q Millipore 18.2 MV $\cdot$ cm resistivity) was used for all dilutions. HNO₃, H₂SO₄, H₂O₂, HF, HClO₄ and HCl were of superior quality (E. Merck). All the plastic and glassware were cleaned by soaking in dilute HNO₃ (1q9) and were rinsed with distilled water prior to use. The element standard solutions used for calibration were prepared by diluting a stock solution of 1000 mg/l (Mn) supplied by Sigma and (Cu, Zn, Fe) by Aldrich (Tuzen, 2003).

A Perkin Elmer A Analyst 700 atomic absorption spectrometer with deuterium background corrector was used in this study. Fe, Cu, K, Mn, Mg, Zn and Na in plant samples were determined by HGA graphite furnace using argon as inert gas. Other measurements were carried out in an air acetylene flame (Tuzen, 2003). The instrumental parameters and operating conditions are given in Table 2.

Table 2. Instrumental analytical conditions of different elements in the plant samples.

Elements	Acetylene flow (L/min)	Air Oxide (L/min)	Wavelength (nm)	Slit width (nm)	Cathode lamp current (mA)
Fe	2.0	17.0	248.3	0.2	30
Cu	2.0	17.0	324.8	0.7	15
Mn	2.0	17.0	279.5	0.2	20
Zn	2.0	17.0	213.9	0.7	15
K	2.0	17.0	766.5	0.7	12
Mg	2.0	17.0	654	0.7	13
Na	2.0	17.0	589	0.2H	0.8

3.5 Statistical analysis

Experimental data was statistically analyzed by applying ANOVA test, the means were subjected to LSD test and differences between samples were determined by F-test using the Statistical Analysis System (SAS, 1998) program. P Values < 0.05 were regarded as significant level (Khan *et al.*, 2008). Correlation between various plant vegetative and reproductive growth parameters was computed using computer software Microsoft Excel.

RESULT AND DISCUSSION

4.1 LABORTERY WORK

I. AM INFECTION IN THE ROOTS AND AMF SPORES IN THE RHIZOSPHERE OF STUDIED LEGUMES AT THREE DIFFERENT STAGES

4.1.1 Root colonization effect by indigenous AMF, *Rhizobium* and Rock phosphate

To access the effect of AM inoculation on of *Vigna radiata* (V₁-V₃) varieties, *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* species and *Lens culinaris* (V₇-V₁₀) varieties were studied at three different stages (vegetative, flowering and fruiting) the results are presented in Tables 3-17. It was seen that the root infection percentage varied in different stages from variety to variety. This agree with the statement that variation in mycorrhizal colonization in different varieties of the same species is well established (Rabbani *et al.*, 2002; Sensoy *et al.*, 2007). Differences among hosts were observed in the amount of hyphae, arbuscules, and vesicles produced by the fungi, which could be attributed to growth and development characteristics among hosts and VAM fungi. Arumugam *et al.* (2010) investigate the effect of *Rhizobium* and Arbuscular mycorrhizal fungi inoculation, both individually and in combination on growth and chlorophyll content of economically important plant *Vigna unguiculata* L. A significant ($p < 0.05$) increase over control in percentage of mycorrhizal infection (96.6 %).

The results showed that the roots of all *Vigna radiata* V₁-V₃, varieties were heavily (90-97%) infected followed by *Lens culinaris* V₇-V₁₀, (86-90%), *Desmodium adscendens* (80-88%), *Macroptilum bracteatum* (80-84%), and *Pisum sativum*, (60-67%). According to the results of the present study the plant showed heavy infection. In all species (V₁-V₁₀) mycorrhizal colonization was gradually increased with the increase in plant age from early vegetative to flowering stage (Tables 3-17). Recently Javaid *et al.* (2007) observed a similar highest mycorrhizal colonization at flowering stage in

another bulbous ornamental plant *Narcissus papyraceus* Ker-Gawl. Similarly, Pongrac *et al.* (2007) observed highest intensity of AM colonization in *Thlaspi praecox* in the flowering phase. The different mycorrhizal developmental pattern in various legumes varieties probably is due to different nutrient requirements in the test varieties at different growth stages. The highest mycorrhizal colonization at late vegetative or at flowering stage in different varieties of legumes indicates that mycorrhizal colonization in this plant species plays an important role in meeting the enhanced nutrient requirements at these growth stages. Although variation in number of arbuscules was recorded in different varieties, however, arbuscular colonization pattern at different growth stages was very similar to one another in different varieties. At early vegetative growth stage, number of arbuscules was comparatively low. Highest number of arbuscules was recorded at late vegetative growth stage in all the varieties except burgundy and desmodium at flowering stage arbuscular colonization was low (Tables 3-17). Arbuscules are the structures where metabolites exchanges take place between the fungus and the host cytoplasm (Parniske, 2000). Arbuscules are short-lived. In most host-fungus interactions, they degenerate within 7 to 12 days (Gadkar *et al.*, 2001). In the present study highest arbuscular colonization at late vegetative growth stage reveals the possibility of maximum metabolic exchange between the symbiotic partners at this growth stage in the test varieties. At early vegetative as well as at flowering stage, there was insignificant difference in number of arbuscules among the varieties. However, at late vegetative growth stage, a marked difference in number of arbuscules was recorded among the varieties. Arbuscules remained high during early stages that dropped in the middle but again become at last harvest (Tables 3-17). In all results it is indicated that roots of studied legumes were colonized by VAMF mycelium, vesicles, and arbuscules were frequently observed. The results in line with Antunes *et al.* (2006), who reported that dually inoculated plants with AMF and *B. japonicum*, soil disturbance significantly affected the development of root colonization by hyphae and arbuscules for both AMF at the early stage. And also there was a positive co-relation between the host plants and development of VAM infections. In general, extent of mycorrhiza increased steadily through the last harvest. The infection increased and reached to optimum at the stage of pod formation (90 days after cultivation). It is evident from Charitha & Reddy (2001)

study that the maximum number of arbuscules, vesicles and spores in dual inoculated plants may be due to the fact that both VAM fungus and *Rhizobium* active in root cortical cells. That means the presence of one symbiont may be influencing the activity of the other. The highest number of arbuscules in *Vigna radiata* was recorded and *Macroptilum bracteatum* followed *Lens culinaris*, *Desmodium adscendens* and *Pisum sativum*. in mycorrhizal colonization among genotypes have also been demonstrated for marigold (Linderman & Davis, 2004), *Capsicum annuum* L. (Sensoy *et al.*, 2007) and tobacco (Janoušková *et al.*, 2007). Regarding the genetic variation of marigold genotypes, or other plants reported in the literature for that matter, there must be variation in P requirements and the morphological and physiological capacity of the plant to acquire P independent of AM colonization. As stated by (Parke & Kaeppler, 2000), P efficiency is reflected in the plant's ability to produce dry matter without the addition of P to the soil or growth medium in the absence of mycorrhizae. The roots become mycorrhizal very soon (20 days after sowing). The levels of mycorrhizal infection steadily rose till the last harvest. The plants inoculated with individual treatment of AM fungi and dual inoculation only shows positive for AM fungi colonization in roots. The *Rhizobium* inoculated plants and uninoculated control plants have very less colonization. The high frequency of 97% of infection was observed in roots of dual inoculated plants roots and 91% in AM fungi inoculated plants roots (Tables 3-17). This is consistent with previous studies showing enhanced levels of root colonization and nodulation resulting from the synergistic effect of dual inoculation, as well as greater nodular dry weights (Meshram *et al.*, 2000; Asad *et al.*, 2004; Heggo & Barakah, 2004; Athar *et al.*, 2005; Mortimer *et al.*, 2008; Singh *et al.*, 2009). Co-inoculation studies with *Rhizobium/rhizobium* spp. have been shown to increase root colonization, shoot biomass, nodule dry matter, nitrogenase activity and nitrogen (N₂)-fixation in chickpea (Hamaoui *et al.*, 2001; Sindhu *et al.*, 2002; Zaidi *et al.*, 2003; Gull *et al.*, 2004; Erdal *et al.*, 2008). At early vegetative as well as at flowering stage, there was insignificant difference in number of arbuscules among the varieties presented in Tables(3-17). However, at late vegetative growth stage, a marked difference in number of arbuscules was recorded among the lentil varieties. The highest number of arbuscules (86.4±0.90) was recorded in NARC-2008-4 V₉ followed by NARC-2002

V₁₀ (82.8±2.36) -NARC-2008V₇ (79.4±0.18) and NARC-2008-3 V₈(61±6.28), shown in Table (17). Variation in mycorrhizal colonization among so been demonstrated for marigold (Linderman & Davis, 2004), *Capsicum annuum* L. (Sensoy *et al.*, 2007) and tobacco (Janoušková *et al.*, 2007). Regarding the genetic variation of marigold genotypes, or other plants reported in the literature for that matter, there must be variation in P requirements and the morphological and physiological capacity of the plant to acquire P independent of AM colonization.

Vesicular colonization pattern at various growth stages was very similar to one another in different legumes varieties. Invariably all the test varieties exhibited an abrupt increase in number of vesicles from early to late vegetative growth stage. Vesicular infection remained low during early stages till flowering. The infection rose to maximum when pegging and fruiting took place. The results agree with the Javaid & Riaz (2008), who reported a significant positive correlation of root and shoot biomasses with different parameters of arbuscular and vesicular colonization in maize.

The levels of extrametrical mycelium were low as compared to internal hyphae shown in Tables 3-17. Results agree with Ruiz-Lozano (2006), who reported that VAM improved the uptake of nutrients by extra radiacal mycorrhizal hyphae. Khan *et al.* (2008) also reported that most prominent contribution of arbuscular mycorrhizal fungi was increased uptake of nutrients by extra-radical mycorrhizal hyphae.

There were great variation among all cultivars because of plant variety and the symbionts involved and some other factors also involved i-e host-symbiotic compatibility, summer and winter conditions, physical, chemical and biological properties of soil and low phosphorus etc. which are clear from our studied plants shown in Tables 3-17. Our results agree with the finding of some workers. Vinicius *et al.* (2010) stated that dual symbiosis formed by AM fungi and *Rhizobium* can be deleterious to *P. vulgaris* growth depending on the plant variety and the symbionts involved. Ampofo (2008) reported that Arbuscular mycorrhiza fungi infection was positively correlated with P concentration. Ampofo (2008) reported that mycorrhizal root infection varied statistically between the AM fungal species and plants (*Gliricidia sepium*). Ampofo (2008) reported that *Rhizobium* inoculation reduced root colonization

by all the *Glomus* species except *Gigaspora rosea*. A highly significant ($P < 0.001$) interaction between mycorrhiza and *Rhizobium* was observed for mycorrhiza colonization of roots. Root colonization by *Glomus clarum* with and without *Rhizobium* inoculation ($Gc+R, Gc-R$) was similar, but the plants differed significantly in growth characteristics. Xavier and Germida (2002) Furthermore, in some instances, for the same *Rhizobium* strain, co-inoculation with one AMF species (92A1 or RGL14+NT4) significantly enhanced the HI compared with the other AMF specie. Vinicius *et al.* (2010) observed that no AM infection was observed in non-inoculated or in single *Rhizobium* inoculated roots. In the L-1 line, the dual inoculation of Rh I+M presented the broadest AM root infection and the Rh I+I showed the lowest. Very high and very low phosphorus levels may reduce mycorrhizal infection/colonization (Koide, 1991). Infection by mycorrhizal fungi is significantly reduced at high soil phosphorus levels (Amijee *et al.*, 1989; Koide & Li, 1990). Studied plants showed high level of growth, productivity and nutrient uptake Tables (44-53). Our results agree with the findings of some workers who stated that colonization of roots by AM fungi has been shown to improve growth and productivity of several field crops (Cavagnaro *et al.*, 2006; Pasqualini *et al.*, 2007) by increasing nutrient element uptake (Karaki, 2006). These fungi are also known to enhance crop growth and yield through enhanced tolerance to various biotic (Khaosaad *et al.*, 2007) and abiotic stress factors (Garni, 2006 & Takeda *et al.*, 2007) and improving physical, chemical and biological properties of soil (Rillig & Mummey, 2006; Cardoso & Kuyper, 2006). Scheublin *et al.* (2006) reported that AMF colonization of the nodules ranged from 5% to 74% and depended on plant species, AMF identity and nutrient availability. Rock phosphate inoculation with AM some time increased the root colonization our result match with Satpal & Kapoor (2000) study the effects of vesicular arbuscular mycorrhizal (VAM) fungi, with and without Mussoorie rock phosphate (MRP) in P-deficient soil with mungbean (*Vigna radiata*) which stimulated root colonization same report by Covacevich *et al.* (2007) that development of AMF is controlled by soil P availability, with higher levels decreasing AMF root colonization. Root colonization of VAM was high with dual inoculation of (VAM+RHZ/VAM+RP) than others treatment Fig. (3-19). Our result correlate with Lukiwat & Simanungkalit (2002) reported that root colonization and

spores number of VAM were significantly higher with dual inoculation than others treatment. Rhizobium and rock phosphate alone have less mycorrhizal colonization as compared to dual inoculation result relate with Arumugam *et al.* (2010) who reported that the plants inoculated with individual treatment of AM fungi and dual inoculation only shows positive for AM fungi colonization in roots. The *Rhizobium* inoculated plants and uninoculated control plants have very less colonization similarly Arumugam *et al.*, (2010) investigate the plants inoculated with individual treatment of AM fungi and dual inoculation only shows positive for AM fungi colonization in roots. The *Rhizobium* inoculated plants and uninoculated control plants do not have colonization. The high frequency of 96% of infection was observed in roots of dual inoculated plants roots and 91% in AM fungi inoculated plants roots. The heavy general AM infection in *Vigna radiata*., *Macroptilum bracteatum*, *Desmodium adscendens*, *Pisum sativum* , and *Lens culinaris*. may be attributed to the deficiency of phosphorus in the soil (we used P deficient soil for experiment phosphorus 1.13%,). Manske (1990) showed that low availability of soil phosphorus increase VAM colonization. In addition, Gryngler & Vancura (1991) observed VAM colonization affected by soil phosphorus. Pragatheswari *et al.* (2004) reported that inoculation of soil with *Glomus mosseae* markedly increased the level of VAM colonization in roots of all plant species, but the extent of VAM colonization in roots decreased at soil solution P level increased and Ortas *et al.* (2001) find out mycorrhizae species to be different in root colonization and dependence ratio in a low-fertility soil with increased "P". Result of AM inoculation on of mung bean, pea ,lentil, burgundy and desmodium varieties were studied for VAM infection to assess the VAM infection at different stages (vegetative, flowering and fruiting) are presented in (Tables 3-17), which revealed that the root infection percentage varied in different stages from variety to variety when the levels (MRP1-MRP2) of rock phosphate+VAM increased as shown in (Tables 3-17) agree with the statement that Antunes *et al.* (2007) reported Plants colonized by arbuscular mycorrhizal (AM) fungi have been shown to respond positively to the application of insoluble forms of inorganic phosphorus (P) such as rock phosphates (RPs). Geneva *et al.* (2006) that effectiveness of coinoculation with *Rhizobium leguminosarum* and *Glomus mosseae* was higher at the low phosphorus level while the coinoculation with *Glomus*

intraradices appeared to be the most effective at higher phosphorus level. But our result also show that the root infection percentage was high at MRP1 but decline on MRP2 as in (Tables 4-17) and in line with the statement that the addition of phosphate fertilization(Rphosphate) results in a delay in infection as well as a decrease in the percentage of infection of roots by mycorrhizae (deMiranda *et al.*, 1989; Asimi *et al.*, 1989) an increase in the level of soil phosphate results in a reduction in chlamydospore production by the fungus (Menge *et al.*, 1978). These spores are involved in root infection and spread of the fungus through the soil profile. Infection by mycorrhizal fungi is significantly reduced at high soil phosphorus levels (Amijee *et al.*, 1989; Koide & Li, 1990).

In the present study *Rhizobiumleguminosarumbv. viceae* strainD 293 and *Rhizobium* strain TAL-169 (*Rhizobium* spp.) were used which are effective and specific *Rhizobium* strain for pea,lentil and mungbean cultivars respectively and combined with VAM for good result the finding of Xavier & Germida (2002) indicated that the efficacy of an effective *Rhizobium* strain on the host was reduced significantly when combined with an incompatible AMF species (NT4+LX81). On the other hand, the efficacy of lentil inoculated with a less effective *Rhizobium* strain was enhanced when combined with a compatible AMF species (e.g. NT6+LX66).

However, the *Rhizobium* sometime were negative as shown in Tables3-5.At fruiting stageVAMF infection decline this agree with correlate with Xavier & Germida (2002), who stated that co-inoculation resulted in significant differences in the AMF colonization levels between the AMF species NT4 and NT6 for the same *Rhizobium* treatment. For example, plants co-inoculated with the NT6+RGL14 combination had significantly higher levels of AMF colonization than the NT4+RGL14 combination. Similarly, plants co-inoculated with the NT4+LX77 combination had a Ca. 2.5-fold increase in AMF colonization over that of the NT6+LX77 combination.

Mycorrhizal colonization of plants inoculated with VAM+RHZ & VAM +RP was higher than single inoculated plants shown inTables 3-17. The present finding are strengthened by work of Charitha & Reddy (2001), who reported that dual inoculation of groundnut with *Rhizobium* and VAM fungus results in significant increase in the

mycorrhizal colonization. Murat *et al.* (2011), who reported that Arbuscular mycorrhizal fungus (AMF) inoculation, alone or in combination with rhizobial inoculation, resulting in large increases root colonization and phosphorus content of the seed and shoot. And other workers have the similar results (Barea *et al.*, 2002; Caravaca *et al.*, 2004; Cabello *et al.*, 2005; Meghvansi & Mahna, 2009).

Thus, dual infection was the most effective for both cultivars with regard to plant growth. These results are in agreement with those obtained by Ahmed & Elsheikh (1998) and Rabie (1998), who found a significant increase in plant dry weight wherever the tripartite association of rhizobia, mycorrhizal fungi and legumes were present it is quite apparent that the combination of VA mycorrhiza and *Rhizobium* was the most effective combination for plant growth, which could be due to the simulative effect of VA mycorrhizal fungi on N fixation through its effect on P uptake.

Table 3.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Vigna radiata* (V₁-V₃)at vegetative stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
Niab-92 V₁*		EH.1	IH.1	VES.1	ARB.1
	Cont.	5.8±0.22	10.2±0.22	18±0.24	27.8±0.38
	VAM	22.2±0.22	32.4±0.23	40±0.47	27±0.28
	Rhz	9.2±0.48	12.6±0.18	34.6±0.36	30.6±0.36
	VAM+Rhz	29.4±0.36	40.6±0.96	47.2±0.46	28.8±0.52
	RP₁	16.6±0.79	19.6±0.18	43.8±0.92	35.4±1.09
	MRP₁	5.6±0.78	9.8±0.26	18.8±0.26	6±0.47
	MRP₂	18.6±0.33	13.8±0.41	27±0.66	10.2±0.26
Niab-98 V₂**	Cont.	8.8±0.22	15.8±0.52	21.2±0.99	24.6±0.61
	VAM	43.3±1.94	38.8±1.83	54.8±1.16	43.2±0.41
	Rhz	11±1.16	15.2±1.70	20.8±0.33	23.8±0.50
	VAM+Rhz	38.8±1.72	38.4±0.81	49.8±1.01	38.6±1.43
	RP₁	13.8±0.65	20.8±0.91	27.8±0.89	20±0.58
	MRP₁	17±0.37	12.6±0.52	24±1.82	35.6±0.91
	MRP₂	19±0.45	14.8±0.83	30.6±0.82	10.8±.26
Niab-2006V₃***	Cont.	10.2±0.17	17.2±0.78	23.4±0.52	27.2±0.92
	VAM	50.8±1.37	47±0.98	62±1.14	48.6±1.90
	Rhz	12.6±0.48	20.6±0.33	22.2±0.50	25.8±0.43
	VAM+Rhz	39.6±1.85	44.6±1.62	51.6±0.90	42.8±1.73
	RP₁	13±0.84	19.4±0.70	27.8±0.89	20±0.57
	MRP₁	17.8±0.48	13.2±0.36	26±1.88	32.4±1.92
	MRP₂	20±2.83	15.4±3.85	32.4±6.95	16.8±6.6

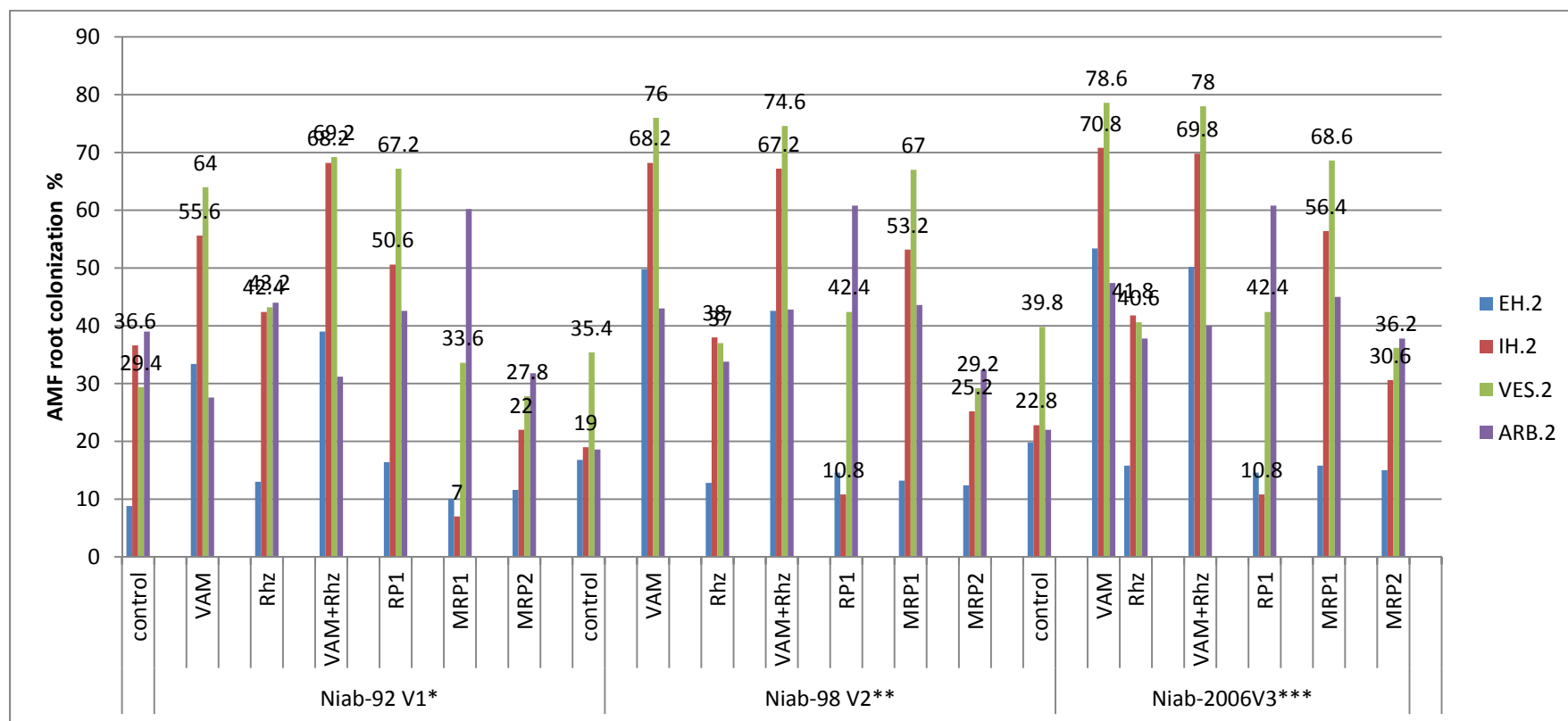


Fig. 1. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Vigna radiata* at vegetative stage.

Table 4.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Vigna radiata*(V₁-V₃) at flowering stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
Niab-92 V₁*		EH.2	IH.2	VES.2	ARB.2
	Cont.	8.8±0.22	36.6±0.27	29.4±0.72	39±0.66
	VAM	33.4±0.18	55.6±0.18	64±0.40	27.6±0.46
	Rhz	13±0.32	42.4±0.52	43.2±0.64	44±0.62
	VAM+Rhz	39±1.03	68.2±0.33	69.2±0.30	31.2±0.33
	RP₁	16.4±0.61	50.6±1.86	67.2±0.22	42.6±0.41
	MRP₁	10±0.55	7±1.30	33.6±1.12	60.2±0.83
	MRP₂	11.6±0.41	22±0.58	27.8±1.02	31.8±1.07
Niab-98 V₂**	Cont.	16.8±0.67	19±0.37	35.4±1.08	18.6±1.84
	VAM	49.8±0.73	68.2±0.33	76±1.59	43±0.40
	Rhz	12.8±1.57	38±0.55	37±0.81	33.8±0.86
	VAM+Rhz	42.6±0.73	67.2±0.48	74.6±1.02	42.8±1.07
	RP₁	14.6±0.63	10.8±1.43	42.4±1.39	60.8±1.11
	MRP₁	13.2±1.57	53.2±1.32	67±0.93	43.6±0.44
	MRP₂	12.4±0.41	25.2±1.05	29.2±0.83	32.4±1.08
Niab-2006V₃***	Cont.	19.8±0.62	22.8±0.48	39.8±1.25	22±1.50
	VAM	53.4±0.36	70.8±0.74	78.6±1.29	47.4±1.29
	Rhz	15.8±1.92	41.8±0.65	40.6±0.90	37.8±0.79
	VAM+Rhz	50.2±1.13	69.8±0.74	78±1.33	40±0.71
	RP₁	14.6±0.63	10.8±1.43	42.4±1.39	60.8±1.11
	MRP₁	15.8±0.65	56.4±0.83	68.6±1.17	45±0.28
	MRP₂	15±2.55	30.6±4.77	36.2±7.69	37.8±9.34

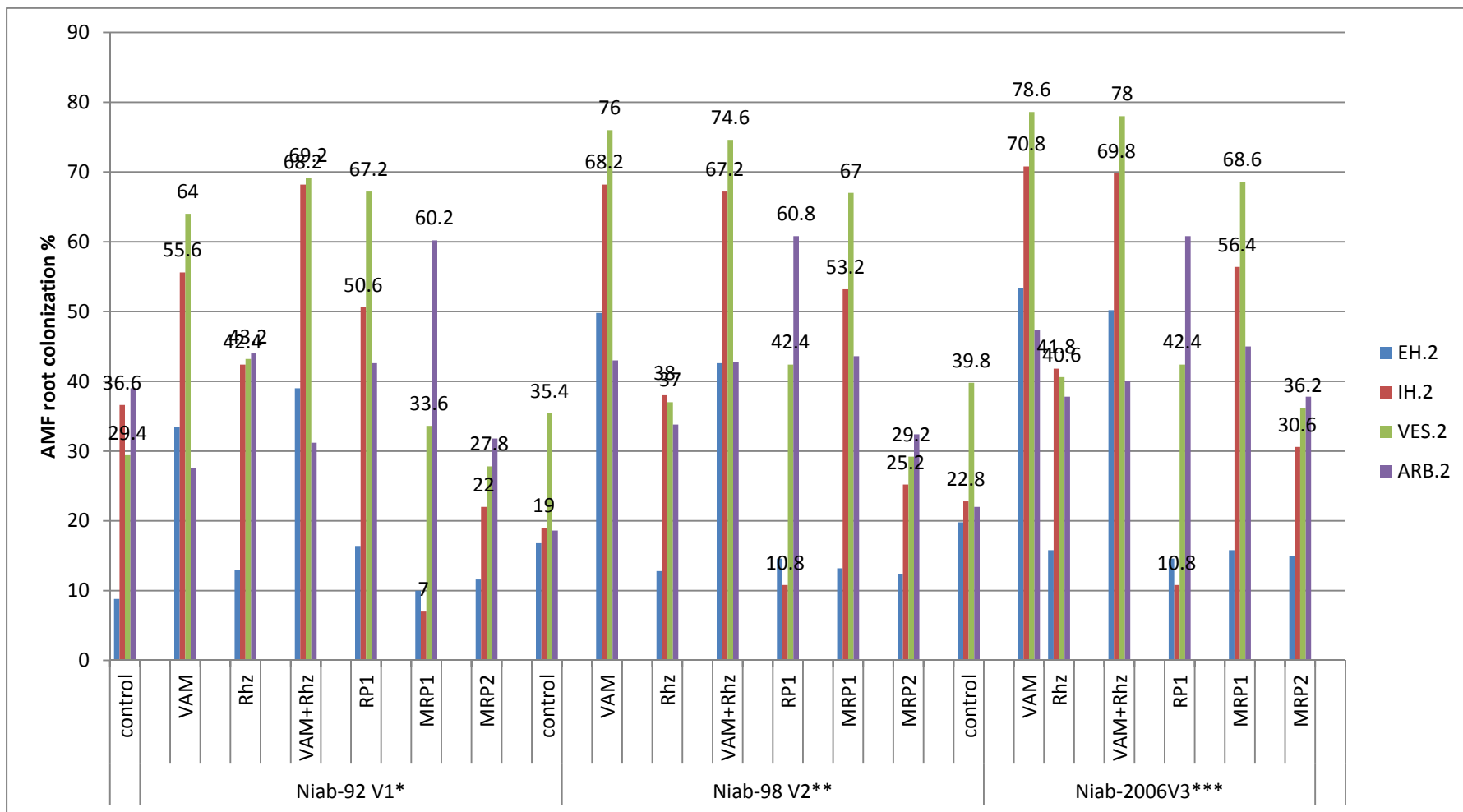


Fig. 2. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Vigna radiata* at flowering stage.

Table 5.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Vigna radiata* (V₁-V₃) at fruiting stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
		EH.3	IH.3	VES.3	ARB.3
Niab-92 V₁*	Cont.	32.6±0.30	50.8±1.03	58±0.40	31.4±0.33
	VAM	53.2±0.93	58±0.28	79.4±0.18	59.4±0.18
	Rhz	39.2±0.67	61.8±0.88	65.2±1.14	33.2±0.22
	VAM+Rhz	63±1.21	69.2±1.44	85.2±1.05	59.2±0.22
	RP₁	73.2±0.75	79.8±1.09	85.2±1.07	76±1.14
	MRP₁	41±1.90	42.4±0.78	67.6±0.41	32.6±1.33
	MRP₂	43.8±0.73	32.4±1.17	35.2±0.97	51.2±0.52
Niab-98 V₂**	Cont.	21.6±1.24	25±0.58	41.4±0.88	18±0.28
	VAM	72.2±0.55	73.8±0.78	89±0.57	96.6±0.93
	Rhz	19.8±0.30	40.6±0.46	55.2±1.89	50.6±0.50
	VAM+Rhz	71±1.20	71.2±0.78	79±1.33	68±0.71
	RP₁	45±1.89	50±2.32	70.8±0.71	29.8±3.59
	MRP₁	72.2±0.80	76.2±0.91	84.8±1.90	72±1.64
	MRP₂	43.8±0.73	32.4±1.17	87.2±0.84	76.2±0.62
Niab-2006V₃***	Cont.	26.6±0.89	31.4±0.36	45.6±0.54	26±1.23
	VAM	75.2±0.89	78.8±1.07	83.2±1.35	67.6±2.70
	Rhz	23.6±0.79	44.4±0.64	61.4±1.13	53.4±1.38
	VAM+Rhz	71±2.55	74±0.60	76.6±1.57	66.8±0.43
	RP₁	45±1.89	50±2.32	70.8±0.71	29.8±3.59
	MRP₁	72.8±1	76.2±0.91	84.4±1.09	72±1.64
	MRP₂	46.4±3.85	40±16.4	87.8±4.38	78.8±6.98

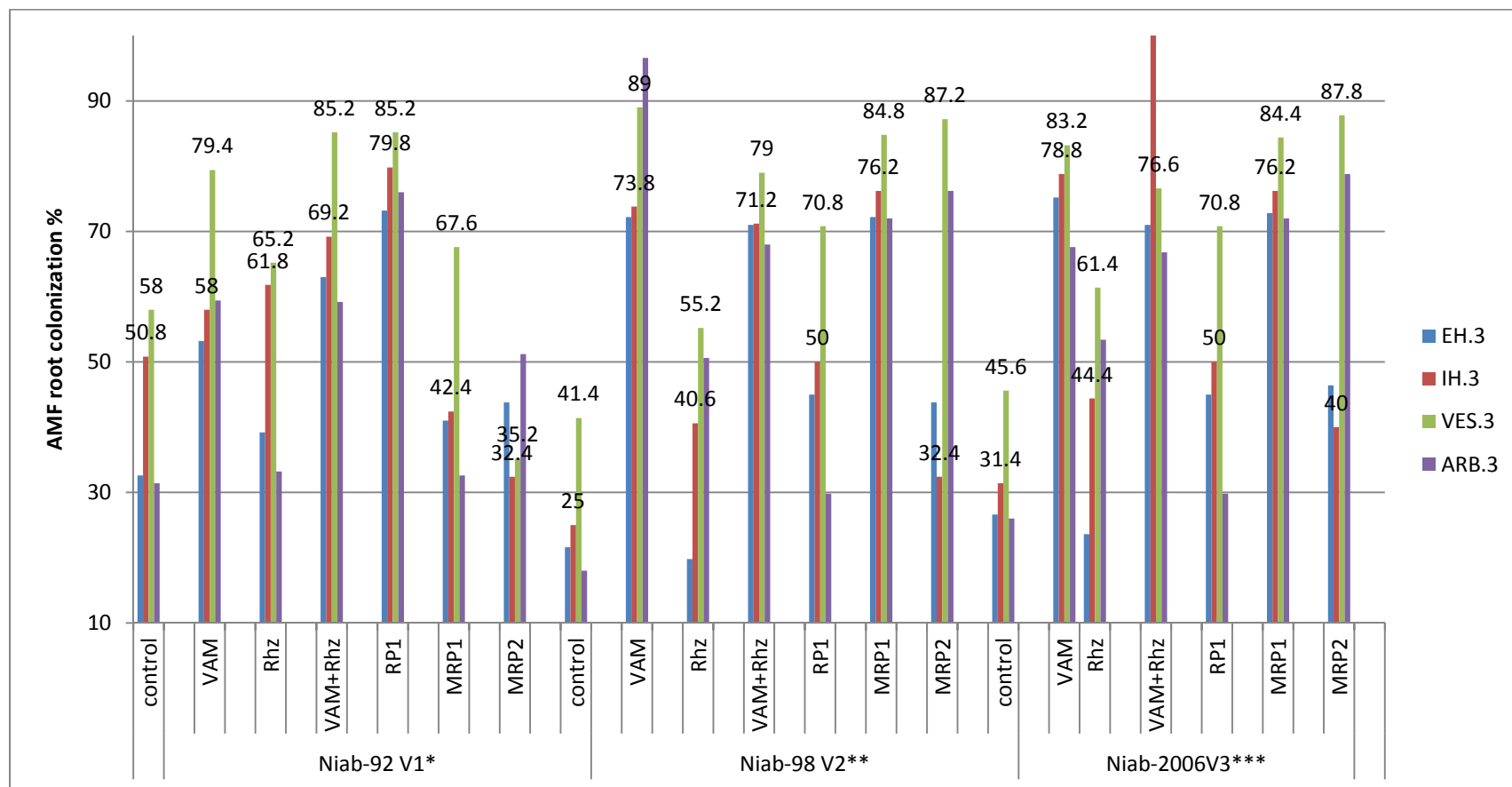


Fig. 3. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Vigna radiata* at fruiting stage.

Table 6.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Macroptilum bracteatum* at vegetative stage.

Treatments	VAMF/ infection or Root assessment			
	EH.1	IH.1	VES.1	ARB.1
Cont.	6.8±0.46	13±0.86	19.8±1.84	12.2±1.20
VAM	27.4±1.20	28.6±3.17	46.2±0.43	34.8±0.75
Rhz	9.8±1.05	14.6±0.97	20.6±0.33	23.2±0.52
VAM+Rhz	37.2±1.73	35.6±0.86	44±1.80	36.6±1.80
RP₁	21.4±0.81	27.4±1.17	36±1.37	27±2.08
MRP₁	17±0.37	12.6±0.52	31±2.81	35.6±0.91
MRP₂	21.2±1.35	17.2±1.89	32.2±0.36	13.8±2.39

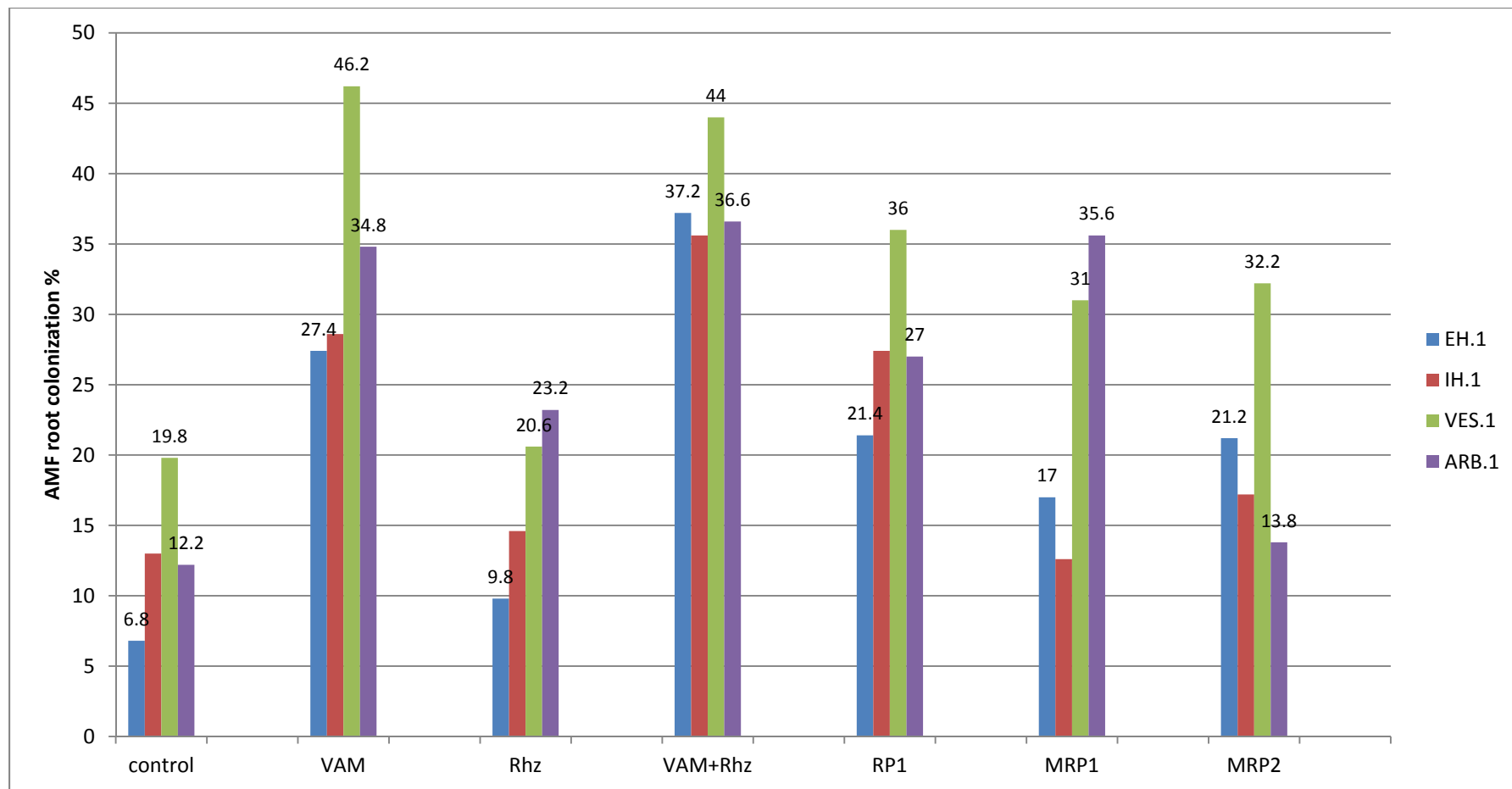


Fig. 4. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Macropitulum bracteatum* at vegetative stage.

Table 7. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Macroptilum bracteatum* at flowering stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
(V ₄)		EH.2	IH.2	VES.2	ARB.2
	Cont.	15.2±0.78	17.8±0.82	31±1.62	15.6±1.82
	VAM	36.8±1.39	50±0.65	63±1.14	39±1.06
	Rhz	15.2±0.74	36.6±0.52	37±0.81	31.8±0.93
	VAM+Rhz	41.2±0.54	65.6±0.77	72.4±1.43	43±1.71
	RP₁	24.2±3.61	20.2±1.73	46.2±0.36	64.6±1.51
	MRP₁	22±2.52	50.8±2.21	62±2.24	48.4±2.05
	MRP₂	12.2±0.26	24.6±2.82	32±1.73	35.2±2.83

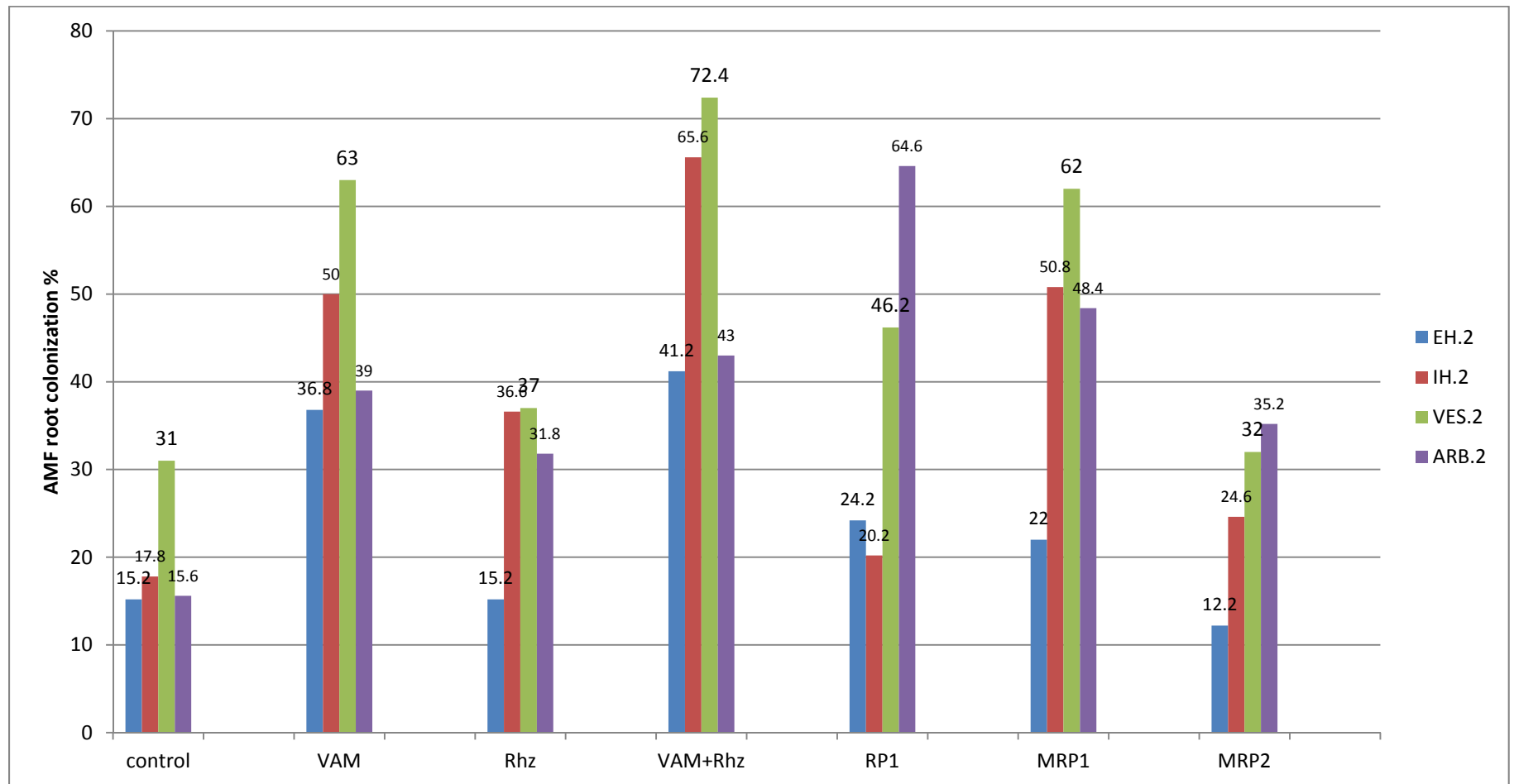


Fig. 5. Vesicular-) arbuscular mycorrhizal root colonization (%) in *Macropitulum bracteatum* at flowering stage.

Table 8. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Macroptilum bracteatum* at fruiting stage.

Treatments	VAMF/ infection or Root assessment			
	EH.1	IH.1	VES.1	ARB.1
Cont.	13.8±0.80	22.8±1.32	41.4±0.88	16.2±0.38
VAM	61.6±1.50	62.6±1.13	79.2±1.35	52.4±3.86
Rhz	17.8±0.67	36.6±1.01	52.8±1.28	45.2±1.34
VAM+Rhz	68±1.30	67.6±1.23	74.8±1.93	64.2±1.27
RP₁	50.8±2.98	52.8±2.20	66.6±0.86	42.8±0.61
MRP₁	72.2±0.80	76.2±0.91	84.8±1.09	72±1.64
MRP₂	42±2.75	41±2.04	75.6±2.47	58.2±2.34

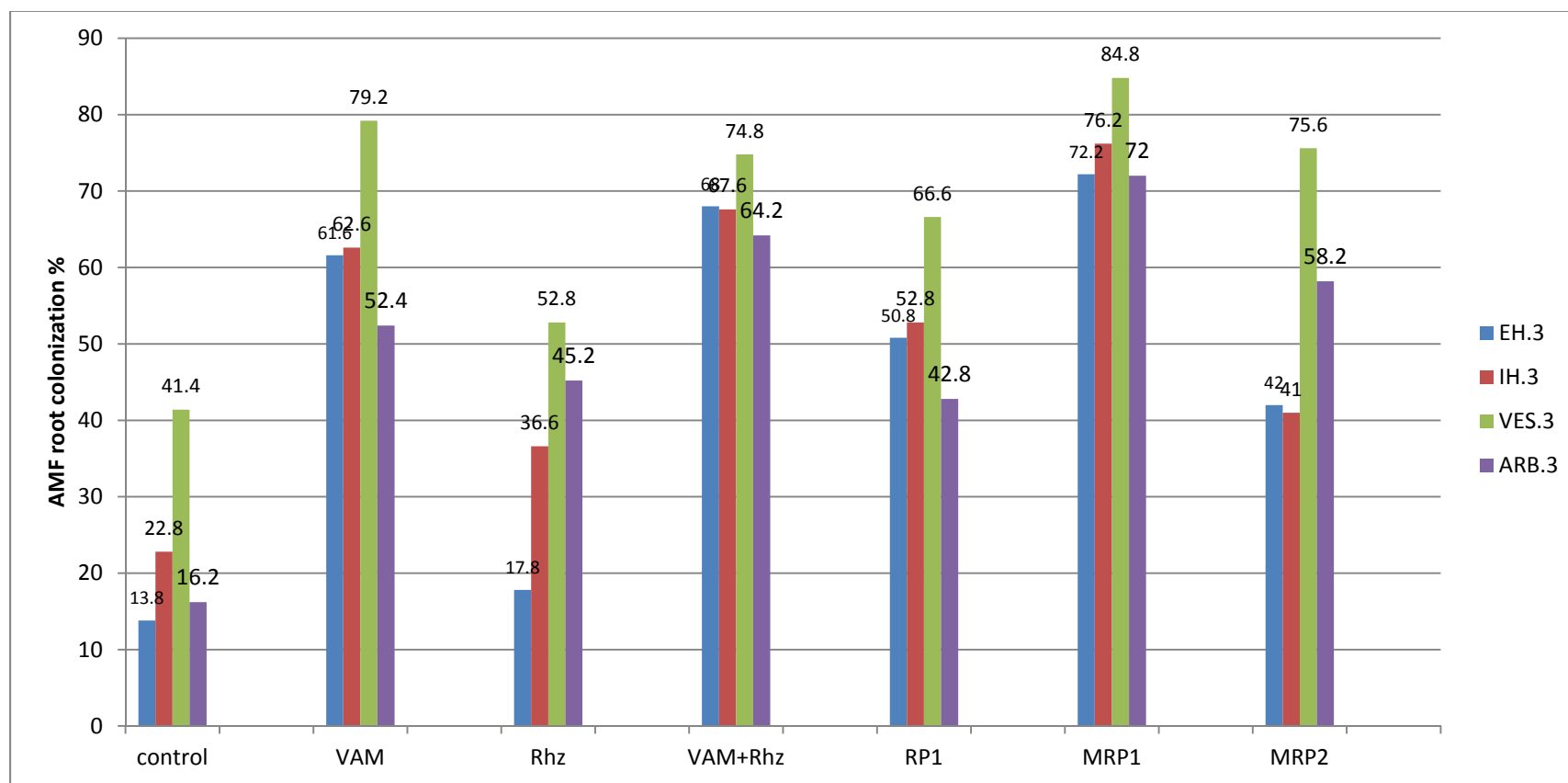


Fig. 6. Vesicular-) arbuscular mycorrhizal root colonization (%) in *Macropitulum bracteatum* at fruiting stage.

Table 9.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Pisum sativum* at vegetative stage.

Treatments	VAMF/ infection or Root assessment			
	EH.2	IH.2	VES.2	ARB.2
Cont.	2.4±0.23	5.8±0.43	12±0.14	13.2±0.43
VAM	4.4±0.23	8.8±0.22	12.4±0.23	15±0.60
Rhz	5.2±0.22	8.6±0.11	15.4±0.18	22.6±1.34
VAM+Rhz	6.6±0.23	11.4±0.33	13±0.20	17.4±0.74
RP₁	11.8±0.33	4.8±0.55	24.4±0.67	24±1.85
MRP₁	2±0.32	5.8±0.43	14.8±0.67	2.4±0.23
MRP₂	1.4±0.10	5.8±0.50	18±0.33	3±0.22

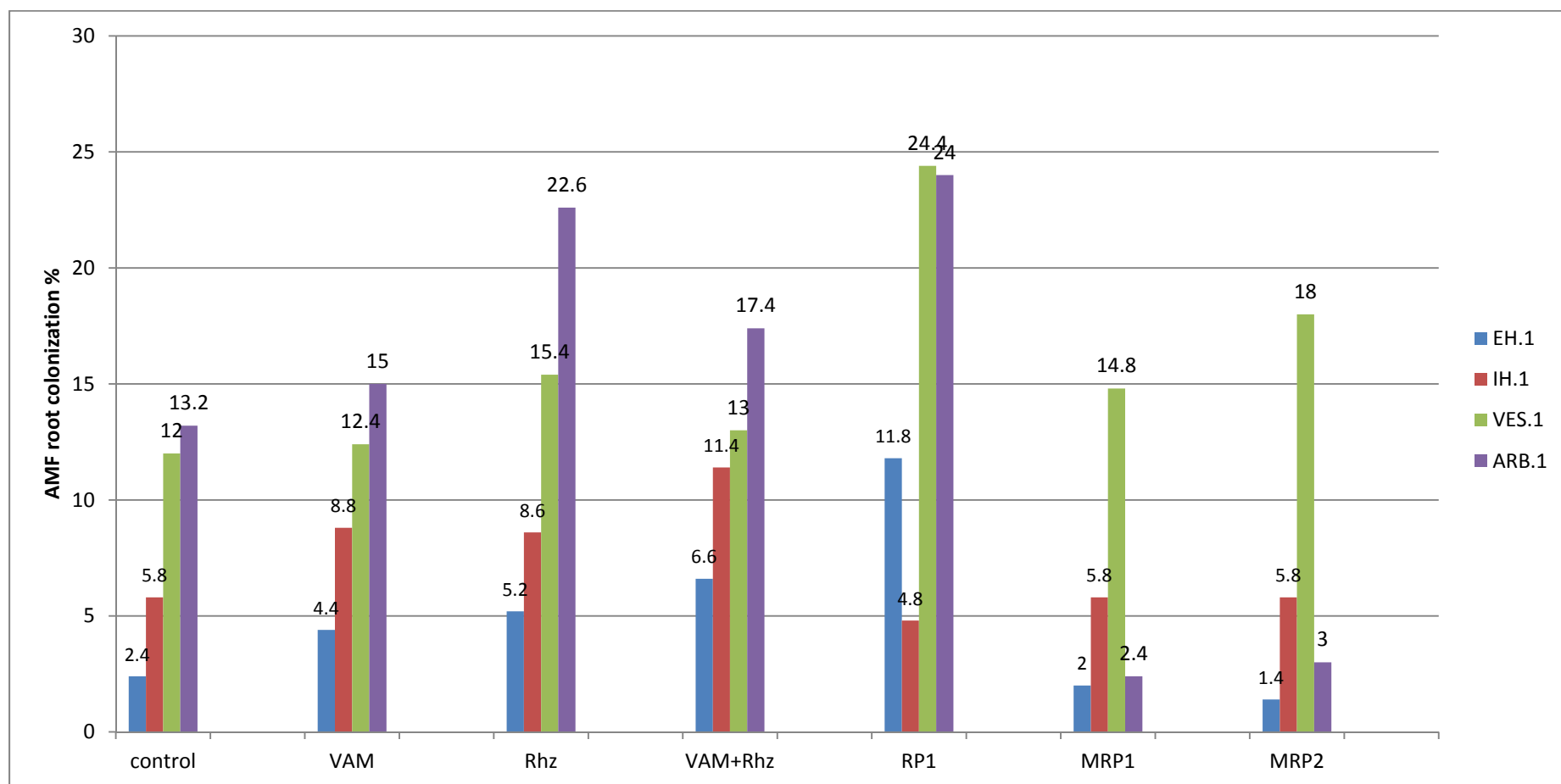


Fig. 7. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Pisum sativum* at vegetative stage.

Table 10. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Pisum sativum*) at flowering stage.

Treatments	VAMF/ infection or Root assessment			
	EH.2	IH.2	VES.2	ARB.2
Cont.	9.6±0.127	9.8±0.55	13.6±0.78	9.6±0.30
VAM	6.2±0.52	21.6±1.21	24±.28	19.2±0.22
Rhz	7.2±0.70	23.8±2.55	27±0.20	39.2±0.22
VAM+Rhz	8.4±0.11	30.2±0.22	25±0.14	18.6±0.88
RP₁	12.8±0.26	37.4±0.78	47.4±3.47	28.8±2.07
MRP₁	5.8±0.43	2±0.14	26.6±0.41	32.6±1.91
MRP₂	8.4±0.47	8.4±1.87	17.2±1.99	28.4±3.26

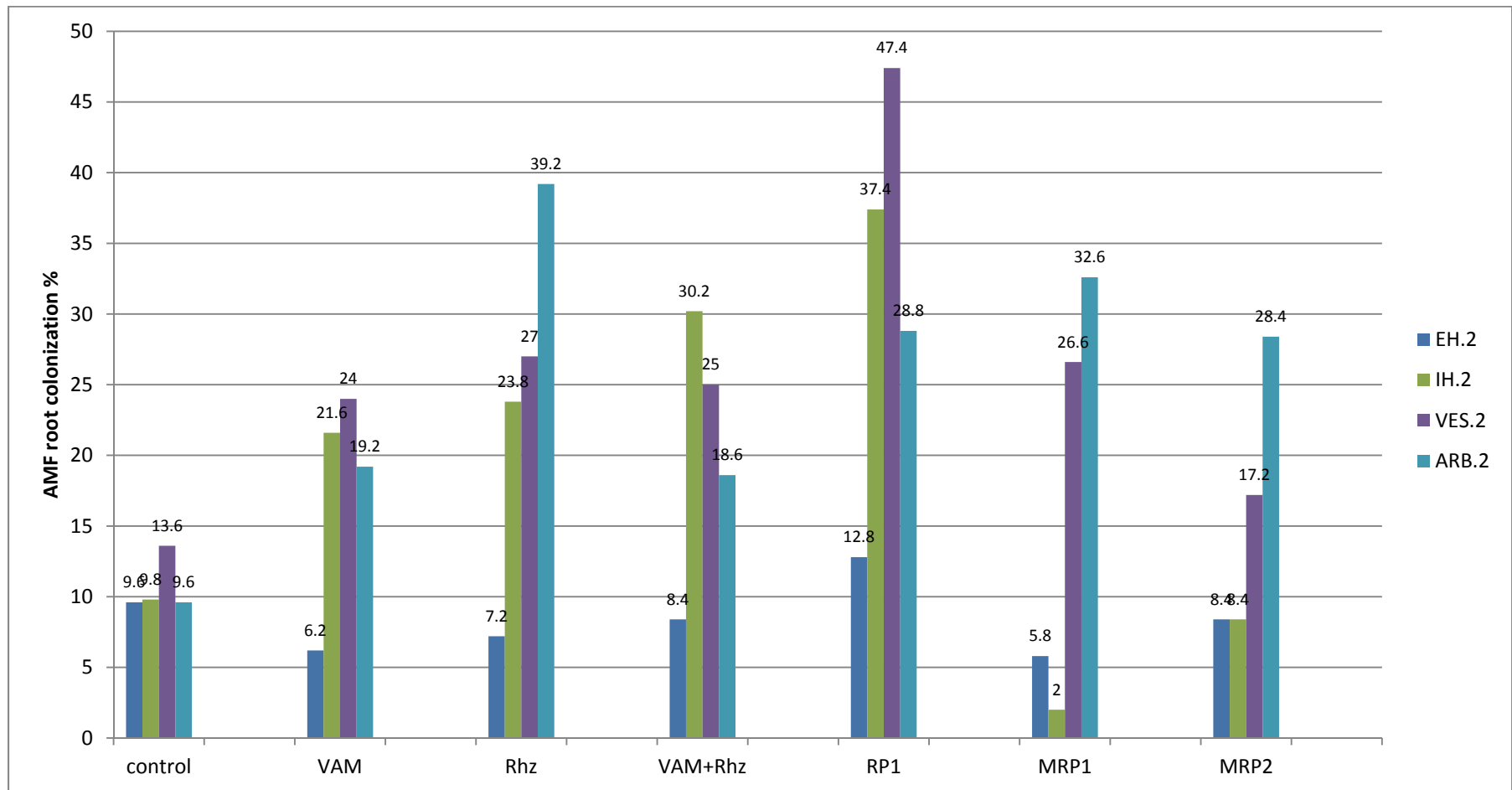


Fig. 8. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Pisum sativum* at flowering stage.

Table 11. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Pisum sativum* at fruiting stage.

Treatments	VAMF/ infection or Root assessment			
	EH.2	IH.2	VES.2	ARB.2
Cont.	14.4±0.23	9.4±0.39	26.6±0.52	7.6±0.33
VAM	12±0.00	25.8±1.66	33.4±2.51	37.2±0.36
Rhz	29.2±0.22	48.6±0.44	49.2±0.22	29.6±0.11
VAM+Rhz	12.4±0.36	31.6±0.41	40±0.28	40±0.32
RP₁	57.8±1.28	64.2±1.58	64.6±2.82	67.6±1.36
MRP₁	24.2±1.01	30.6±0.98	53.4±1.14	26.2±0.71
MRP₂	28.6±0.88	32.6±1.14	60.6±1.07	29.4±1.25

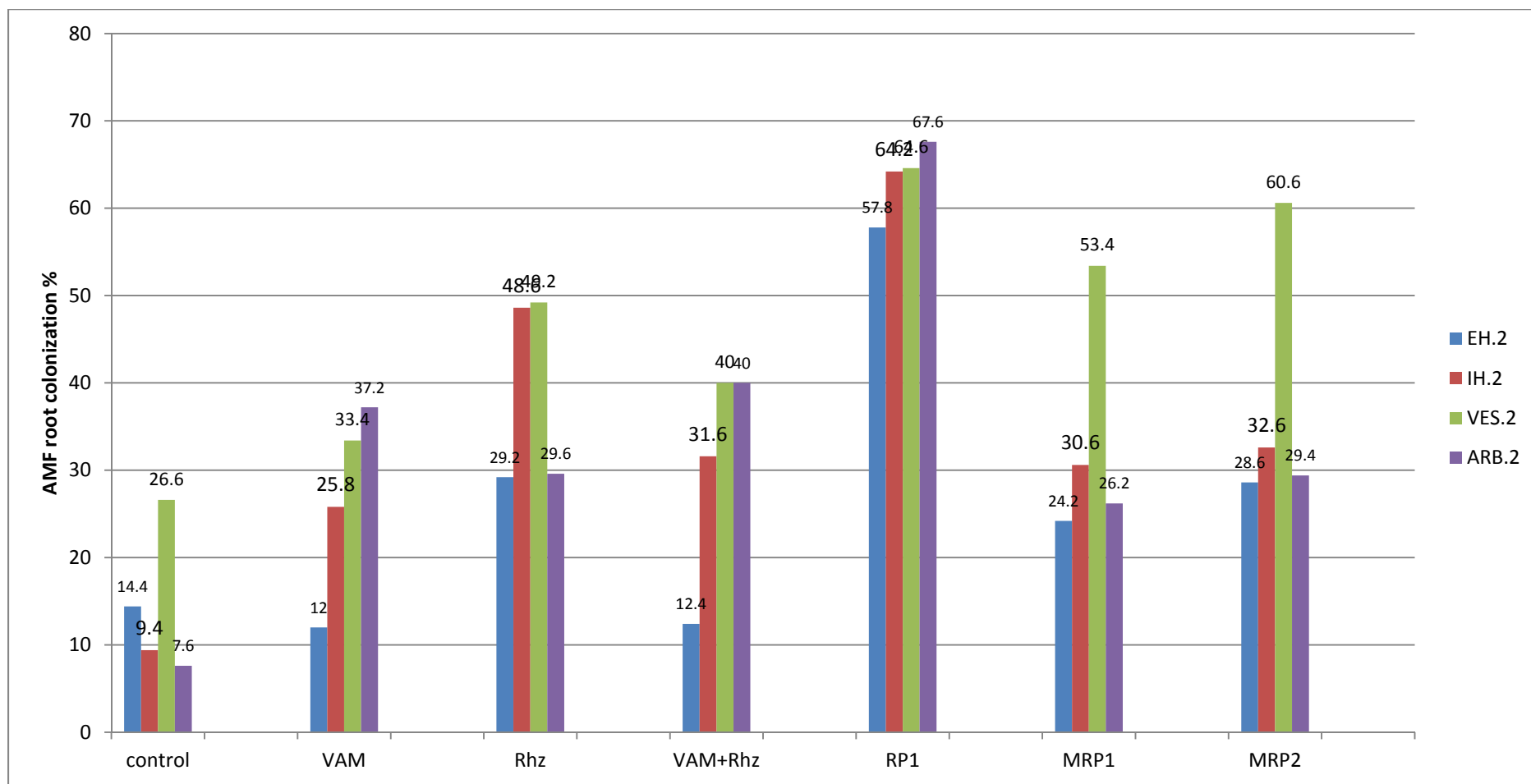


Fig. 9. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Pisum sativum* at fruiting stage.

Table 12.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Desmodium adscendens* at vegetative stage.

Treatments	VAMF/ infection or Root assessment			
	EH.1	IH.1	VES.1	ARB.1
Cont.	6±0.76	10.2±0.88	6.2±0.98	14.8±0.22
VAM	9.4±0.23	15.6±0.23	7.6±0.50	21.6±0.41
Rhz	20.4±1.01	12.8±0.22	9.4±0.87	11.6±0.46
VAM+Rhz	33.2±1.35	36.2±0.36	6.6±0.83	42.4±0.48
RP₁	4.2±0.55	8.8±0.30	9.8±0.38	4.6±0.41
MRP₁	5.6±0.78	9.8±0.26	8.8±0.26	6±0.47
MRP₂	8±0.55	12.6±0.18	34.6±0.36	30.6±0.36

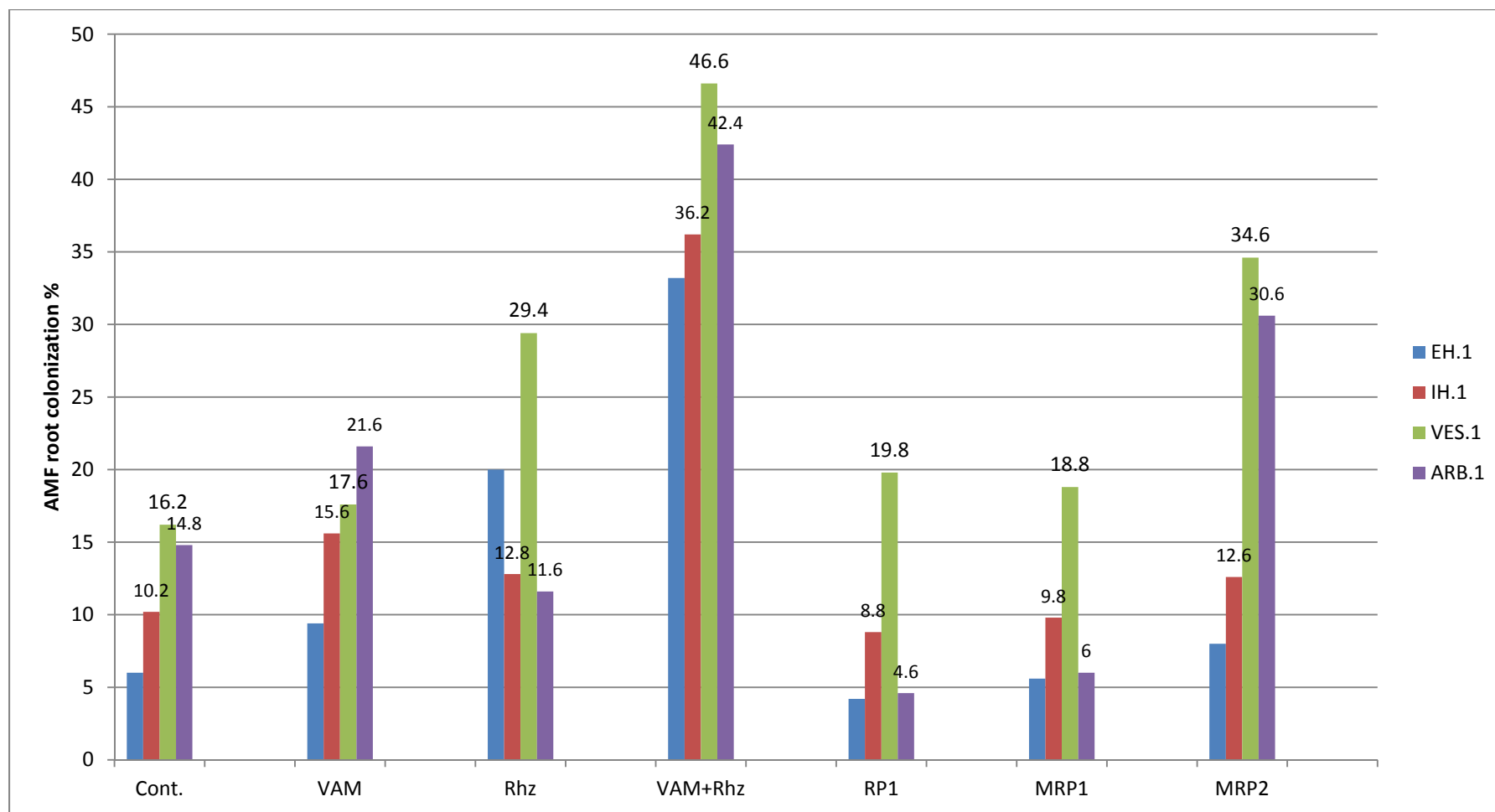


Fig.10. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Desmodium adscendens* at vegetative stage.

Table 13.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Desmodium adscendens* at flowering stage.

Treatments	VAMF/ infection or Root assessment			
	EH.2	IH.2	VES.2	ARB.2
Cont.	10.6±0.27	13±0.28	14.4±0.33	8.4±0.11
VAM	13.4±0.36	32±0.32	33.2±0.26	26.6±0.36
Rhz	11.6±0.41	22±0.58	27.8±1.02	31.8±1.07
VAM+Rhz	39.6±0.89	63.6±0.70	74.2±1.01	40.2±0.55
RP₁	9.6±0.23	6.8±0.50	25.4±2.64	58.4±1.78
MRP₁	10±0.55	7±1.30	33.6±1.12	60.2±0.83
MRP₂	10.6±0.54	42.4±0.5	43.2±0.64	44±0.62

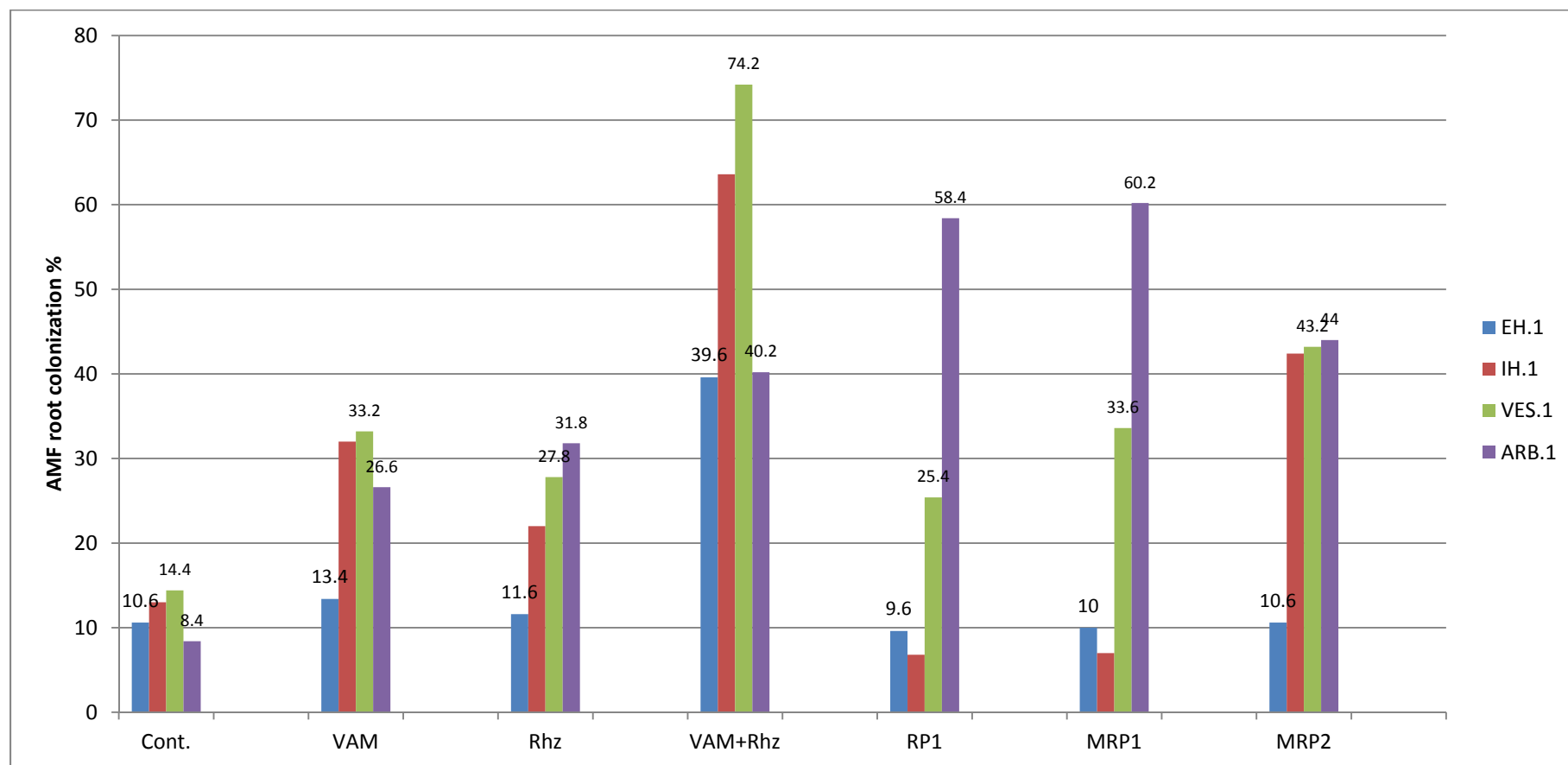


Fig.11. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Desmodium adscendens* at flowering stage.

Table 14.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Desmodium adscendens* at fruiting stage.

Treatments	VAMF/ infection or Root assessment			
	EH.3	IH.3	VES.3	ARB.3
Cont.	15.2±0.17	11±0.20	27.8±0.38	8.6±0.11
VAM	17.4±0.18	36.4±0.46	47.2±0.62	46.4±0.46
Rhz	43.8±0.73	32.4±1.17	35.2±0.97	48.8±0.71
VAM+Rhz	68.4±0.63	69.4±0.30	88±0.49	91.6±1.04
RP₁	37.8±0.91	43.6±0.58	69±0.20	39.8±1.23
MRP₁	41±1.90	42.4±0.78	67.6±0.41	32.6±1.33
MRP₂	39.2±0.67	54.4±1.53	65.2±1.14	36.6±1.11

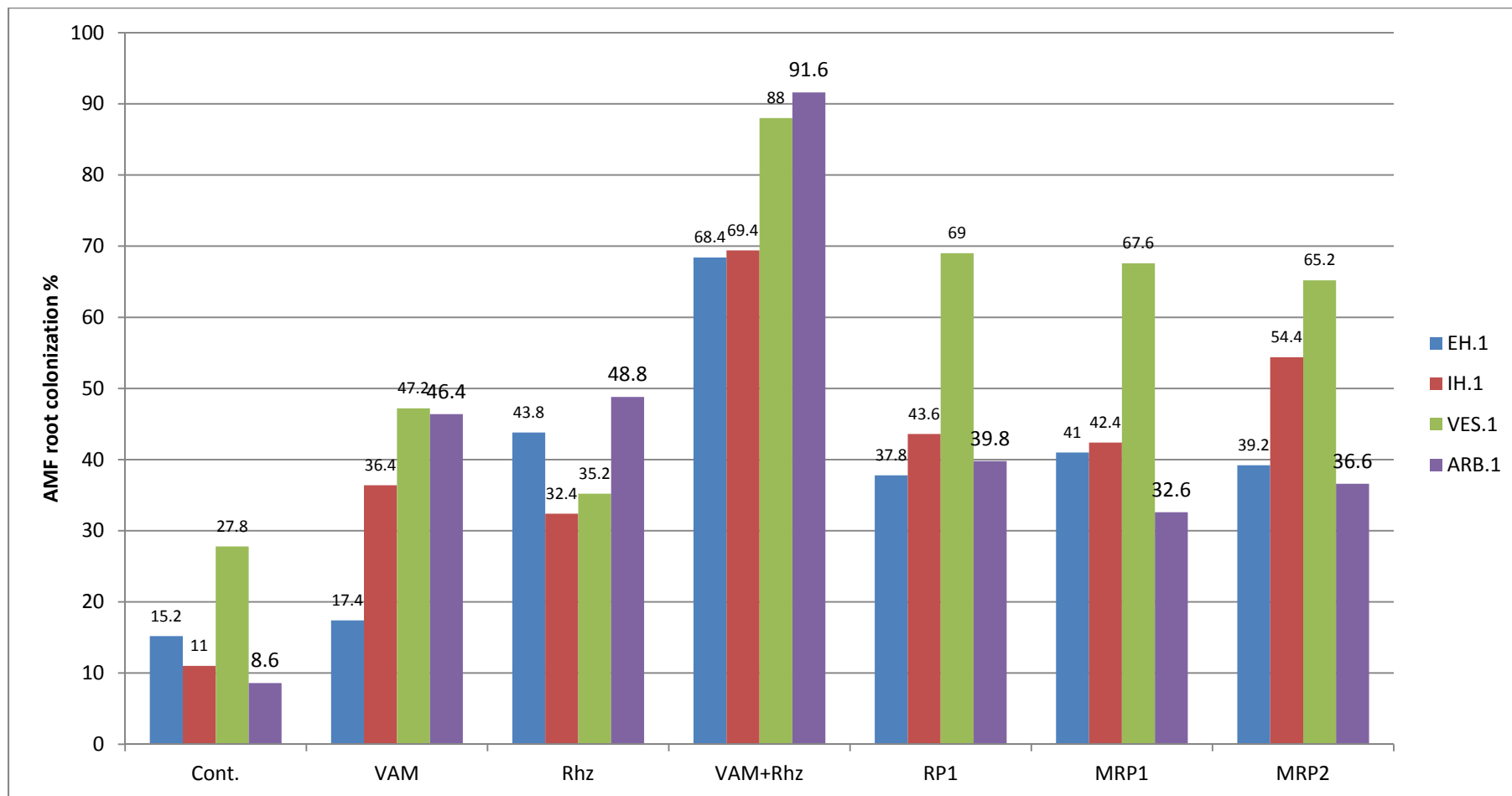


Fig.12. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Desmodium adscendens* at fruiting stage.

Table 15.(Vesicular-) arbuscular mycorrhizal root colonization (%) in *Lens culinaris* (V₇-V₁₀) at vegetative stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
		EH.1	IH.1	VES.1	ARB.1
NARC-2008-2 V_{7**}	Cont.	3.8±0.22	6.2±0.46	8.2±0.92	10.6±0.86
	VAM	8.6±0.11	22.4±3.98	15.6±0.18	19.6±0.18
	Rhz	6.8±0.36	10.4±0.18	19.6±0.18	30.2±0.22
	VAM+Rhz	23.6±0.18	33.4±0.18	39.4±0.18	27.6±0.18
	RP₁	18.4±0.33	10±0.24	36.6±1.20	39.4±0.18
	MRP₁	3.6±0.18	8.8±0.09	19.6±0.18	4±0.00
	MRP₂	17.2±0.22	12.4±0.18	25.2±0.22	9.2±0.09
	Cont.	2.8±0.22	7.5±0.20	12.8±0.22	14.8±0.22
NARC-2008-3 V_{8*}	VAM	5.2±0.22	9.6±0.11	1±0.20	18±0.28
	Rhz	5.2±0.22	8.6±0.11	15.4±0.18	25.2±0.36
	VAM+Rhz	6.6±0.23	11.4±0.33	1±0.20	19.2±0.22
	RP₁	14±0.55	7±0.32	25.6±0.90	34.6±1.06
	MRP₁	2.4±0.23	6.8±0.30	17±0.28	2.6±0.18
	MRP₂	2±0.13	8.2±0.15	18.8±0.23	3.6±0.10
	Cont.	4.4±0.18	7.4±0.54	10.4±0.82	12.8±0.94
	VAM	9.4±0.23	15.6±0.23	17.6±0.50	21.6±0.41
NARC-2008-4 V_{9***}	Rhz	5.6±0.30	11±0.20	17.2±0.79	28.6±0.79
	VAM+Rhz	26.6±0.23	36.4±0.36	42±0.49	32.4±0.56
	RP₁	2.6±0.27	9.80±0.33	22.6±0.72	4.6±0.18
	MRP₁	15.4±0.67	8.4±0.48	27.8±1.09	37.4±0.73
	MRP₂	18.6±0.33	13.8±0.41	27±0.66	10.2±0.26
	Cont.	6.4±0.36	12±0.79	15.2±0.52	23.4±0.61
	VAM	12.8±0.41	18±0.20	21±0.20	25±0.37
	Rhz	5.6±0.30	13.6±0.48	19.2±0.43	28.6±0.79
NARC-2002 V_{10****}	VAM+Rhz	33.2±1.35	36.2±0.36	46.6±0.83	42.4±0.48
	RP₁	2.4±0.23	6.8±0.30	17±0.28	2.6±0.18
	MRP₁	2.6±0.11	8.8±0.30	19.8±0.38	4.6±0.41
	MRP₂	2.6±0.11	8.8±0.30	19.8±0.38	4.6±0.41
		16.6±0.30	11±0.24	25±1.64	37.4±0.73

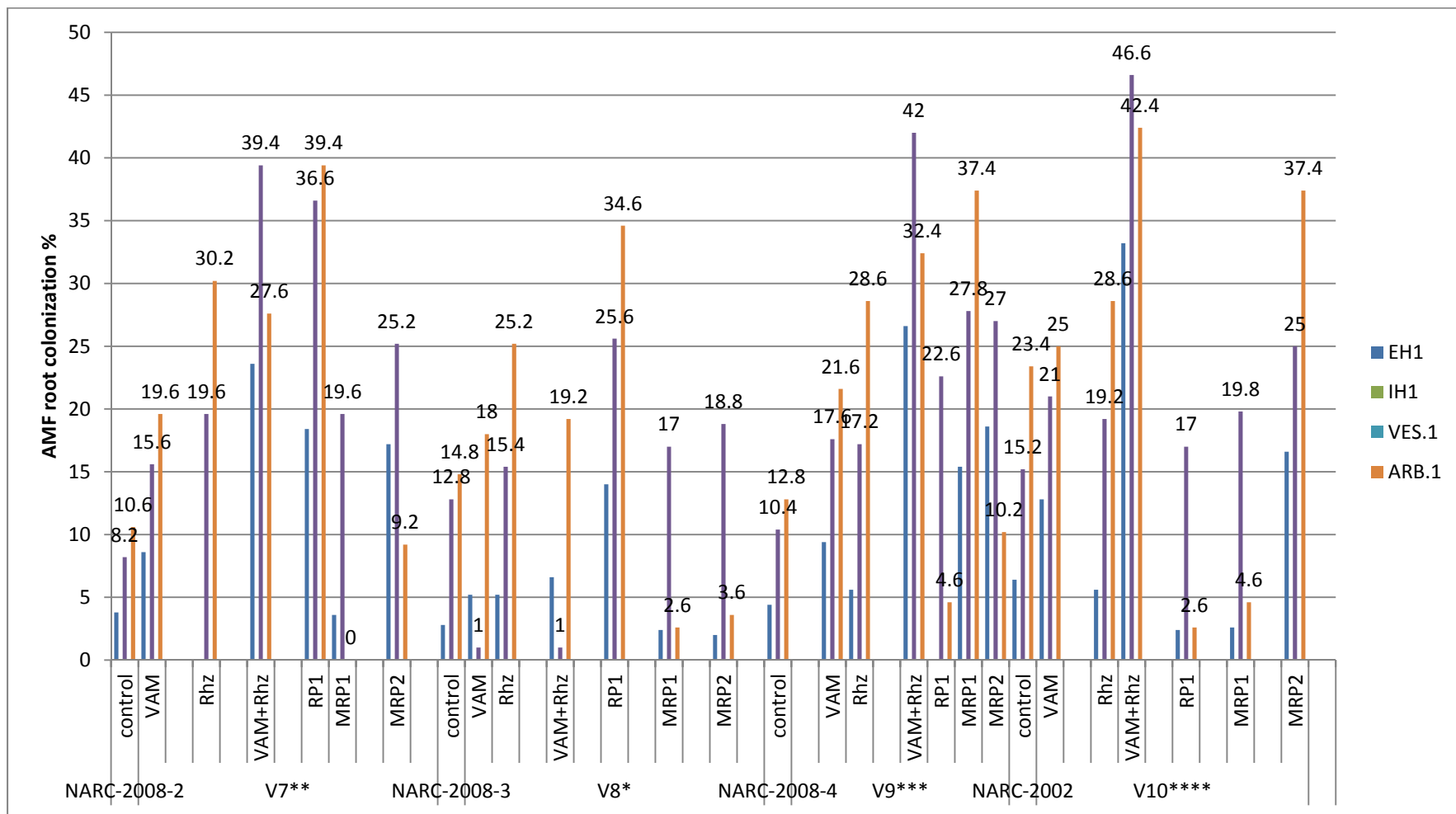


Fig.13. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Lens culinaris* (V₇-V₁₀) at vegetative stage.

Table 16. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Lens culinaris* (V₇-V₁₀) at flowering stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
		EH.2	IH.2	VES.2	ARB.2
NARC-2008-2 V_{7**}	Cont.	8.4±0.23	12.4±0.33	20±0.52	10±0.18
	VAM	10.2±0.22	29.2±0.22	29.8±0.30	23.2±0.36
	Rhz	9.4±0.18	39.6±0.18	33.4±0.18	41.2±0.22
	VAM+Rhz	33.4±0.18	55.6±0.18	63.2±0.22	29.6±0.18
	RP₁	15.8±0.09	59.2±0.22	81.2±0.22	43.6±0.18
	MRP₁	9.4±0.18	0±0.00	33.6±0.18	64.4±0.18
	MRP₂	9.8±0.09	19.2±0.22	22.8±0.22	24.2±0.18
NARC-2008-3 V_{8*}	Cont.	10.6±0.27	13±0.28	14.4±0.33	8.4±0.11
	VAM	0.00±0.00	24.2±0.26	24±0.28	19.2±0.22
	Rhz	8.6±0.11	29.2±0.22	27±0.20	39.2±0.22
	VAM+Rhz	8.4±0.11	30.2±0.22	25±0.14	20±0.32
	RP₁	13.6±0.11	46±1.20	62.8±0.78	36.6±0.33
	MRP₁	7.2±0.30	1.2±0.17	27.6±0.36	45.6±1.32
	MRP₂	8.4±0.27	1.6±0.32	31.2±0.34	58.6±0.30
NARC-2008-4 V_{9***}	Cont.	13.4±0.36	32±0.32	33.2±0.26	26.6±0.36
	VAM	9±0.28	38.4±0.33	32.6±0.33	36.6±1.01
	Rhz	34.8±0.38	61±0.87	73.6±0.86	37.4±0.84
	VAM+Rhz	10.4±0.46	2.6±0.46	27.4±3.08	51.6±5.77
	RP₁	14.8±0.17	50.6±0.94	65.6±0.77	39.6±0.23
	MRP₁	11.6±0.41	22±0.58	27.8±1.02	31.8±1.07
	MRP₂	12.4±0.33	15±0.40	27.2±0.79	11.6±2.12
NARC-2002 V_{10****}	Cont.	16.2±0.65	36.6±0.64	34.4±0.23	29.2±0.41
	VAM	10±0.24	38.8±0.36	36.4±0.76	38.6±1.22
	Rhz	39.6±0.89	63.6±0.70	74.2±1.01	40.2±0.55
	VAM+Rhz	7.2±0.30	1.2±0.17	27.6±0.36	45.6±1.32
	RP₁	9.6±0.23	4.8±0.79	25.4±2.64	58.4±1.78
	MRP₁	9.6±0.23	4.8±0.79	25.4±2.64	58.4±1.78
	MRP₂	12±1.35	50.6±0.94	66.4±0.84	41.8±0.43

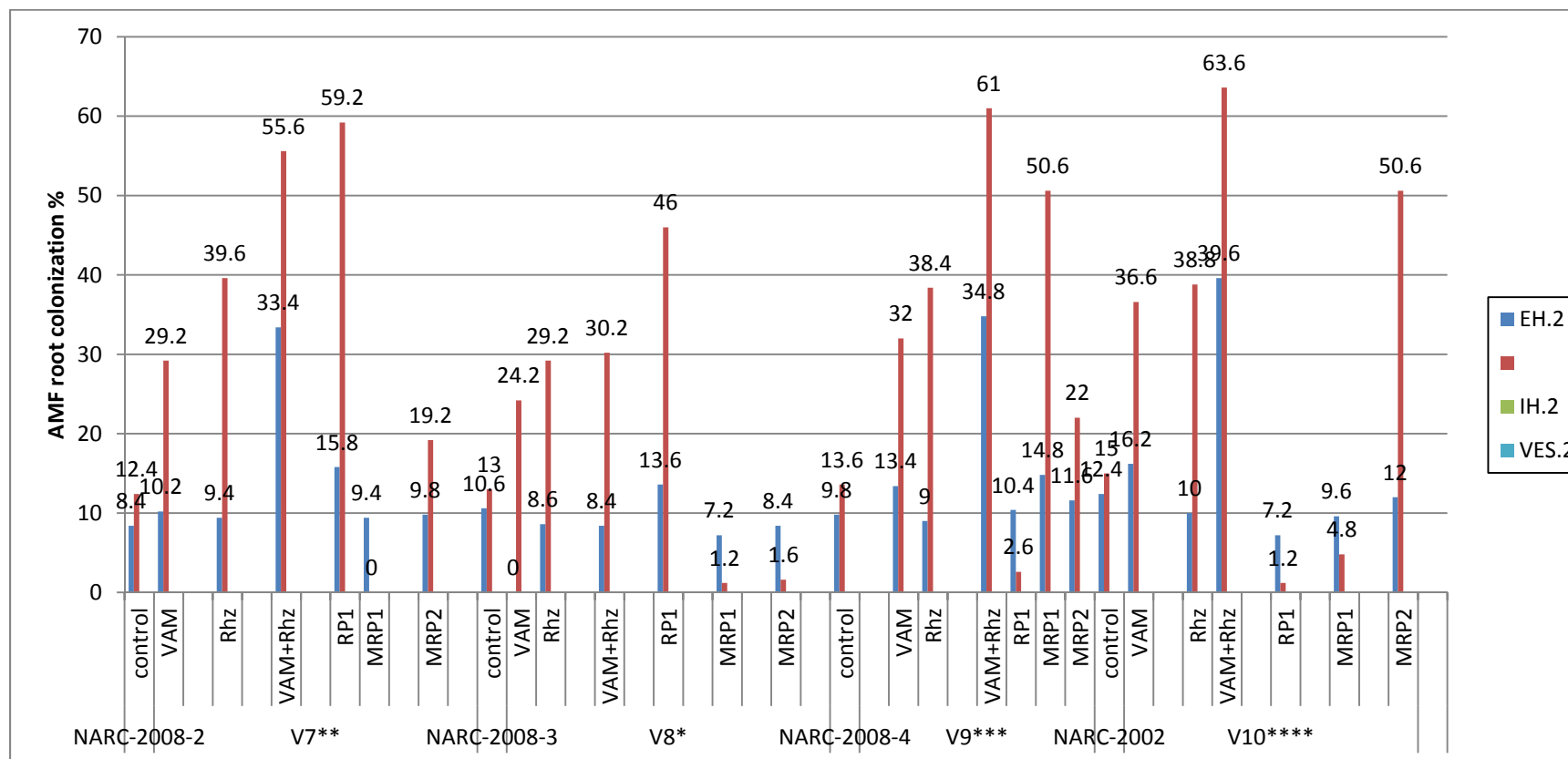


Fig.14. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Lens culinaris* (V₇-V₁₀) at flowering stage.

Table 17. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Lens culinaris* (V₇-V₁₀) at fruiting stage.

Varieties	Treatments	VAMF/ infection or Root assessment			
		EH.3	IH.3	VES3	ARB.3
NARC-2008-2 V_{7**}	Cont.	16±0.28	18±0.18	32±0.22	9±0.48
	VAM	16±0.28	33±0.22	46.6±0.39	43.2±0.22
	Rhz	33.6±0.18	59.2±0.22	58.8±0.36	33.2±0.22
	VAM+Rhz	55.2±0.22	59.2±0.22	79.4±0.18	59.4±0.18
	RP₁	79.2±0.22	79.2±0.22	89.4±0.18	79.4±0.18
	MRP₁	35.2±0.22	41.6±0.18	69.2±0.22	38.6±0.33
	MRP₂	39.6±0.18	27.6±0.18	30.4±0.18	49.2±0.22
NARC-2008-3 V_{8*}	Cont.	15.2±0.17	11±0.20	27.8±0.38	8.6±0.11
	VAM	12±0.00	29.2±0.22	38.8±0.22	37.2±0.36
	Rhz	29.2±0.22	48.6±0.44	49.2±0.22	29.6±0.11
	VAM+Rhz	12.4±0.36	31.6±0.41	40±0.28	40±0.32
	RP₁	68.6±0.26	71.4±0.73	80±0.24	61±6.28
	MRP₁	27.4±0.87	35±0.47	60.4±0.67	28.4±0.88
	MRP₂	34.2±0.20	40.6±0.24	67.6±0.37	36.8±0.27
NARC-2008-4 V_{9***}	Cont.	16.6±0.30	16.4±0.23	34.4±0.23	9.4±0.18
	VAM	17.4±0.18	36.4±0.46	47.2±0.62	46.4±0.46
	Rhz	31.4±0.33	56±0.42	57.4±0.39	30.2±0.57
	VAM+Rhz	65.8±0.84	66.8±0.70	84.8±0.62	86.4±0.90
	RP₁	36.4±0.44	44.8±0.67	70.4±0.44	45.8±1.16
	MRP₁	70.4±0.36	72.8±0.93	84.4±1.01	77.2±1.47
	MRP₂	43.8±0.73	32.4±1.17	35.2±0.97	51.2±0.52
NARC-2002 V_{10****}	Cont.	16±1.22	17.6±0.33	37.6±0.70	12.2±0.38
	VAM	18.8±0.17	38.2±0.26	48±0.95	47±0.576
	Rhz	35.2±0.71	57.8±0.4	57.4±0.39	31.6±0.54
	VAM+Rhz	68.4±0.6	69.4±0.30	88±0.49	91.6±1.04
	RP₁	25.2±0.70	34.2±0.65	60.4±0.67	28.4±0.88
	MRP₁	37.8±0.91	43.6±0.58	69±0.20	42.2±0.82
	MRP₂	37.8±0.91	43.6±0.58	69±0.20	42.2±0.82
		70.4±0.36	75.4±0.82	84.4±1.01	82.8±2.36

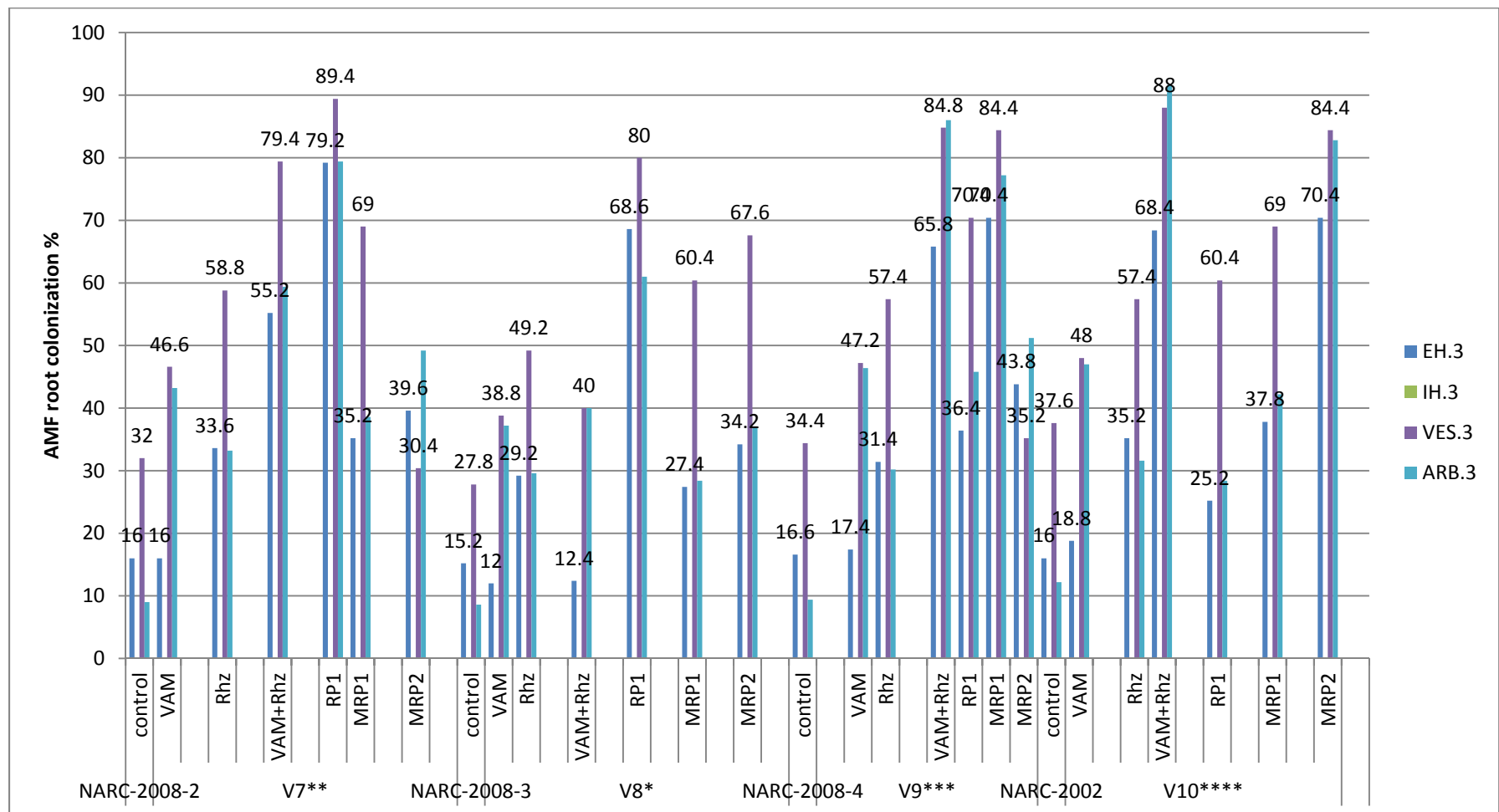


Fig.15. (Vesicular-) arbuscular mycorrhizal root colonization (%) in *Lens culinaris* (V₇-V₁₀) at fruiting stage..



Fig. 16. An oblong large sized thick walled vesicles conjugated with other thick walled smaller vesicles in root cortex. of *Vigna radiata* (100x).

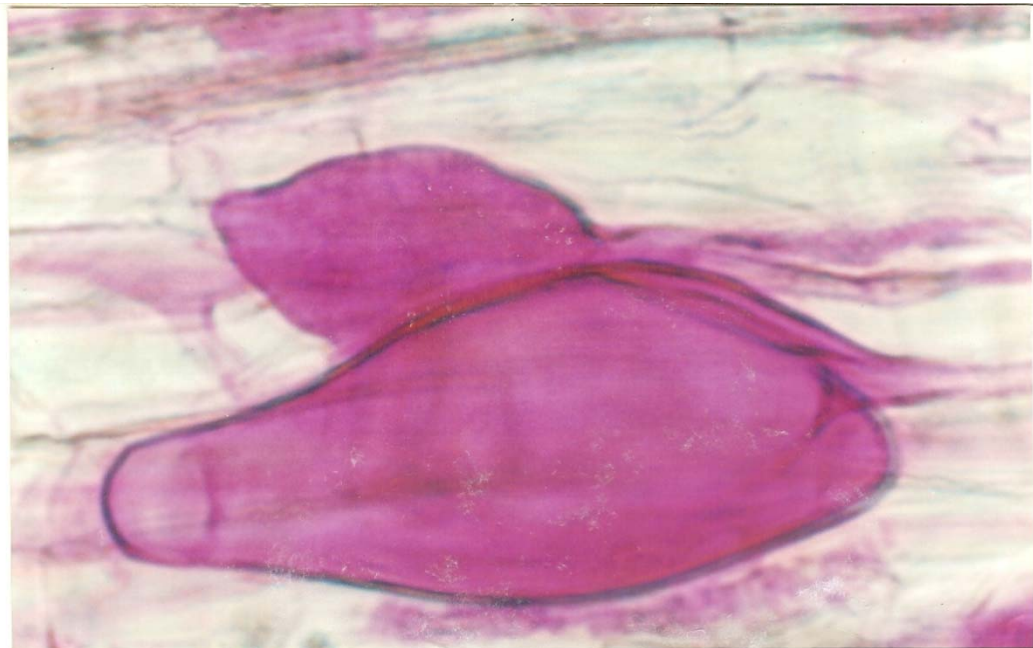


Fig. 17. Thick walled Vesicles of different shapes in root cortex of *Pisum sativum* (100x).

4.2 Effect of indigenous AMF, *Rhizobium* and Rock phosphate on Spores density

All values mean $\pm$ SEM of V₁-V₁₀ are shown in Tables(18-32) and Fig.(20--38). In all species (V₁-V₁₀) spores density gradually increased with the increasing plant age from early vegetative to fruiting stage (Tables 18-32). The highest number of spores was recorded for *Vigna radiata* (V₁-V₃) followed by *Macroptilum bracteatum*, *Lens culinaris*, *Desmodium adscendens* and *Pisum sativum*. Our results are in conformity with the finding of workers (Jalal-ud-Din & Anwar, 1991; Ezawa *et al.*, 1995; Fattah & Razak, 1996) who also reported the positive relationship between the VAM development and the age of the host plant. In general the mycorrhizal infection increased with the age of the host plant. Javaid *et al.* (2007) reported a similar highest mycorrhizal colonization at flowering stage in *Narcissus papyraceus*. Similarly, Pongrac *et al.* (2007) observed highest intensity of AM colonization and spore density in *Thlaspi praecox* in the flowering phase. And similarly Ray & Valsalakumar (2010) reported that spore count in the soil after harvest also explains the successful interaction of the crop with AM fungal associations. The plants inoculated individually with AM fungi /RP and *Rhizobium* or dual inoculation showed positive for AM fungi colonization in roots. The RP inoculated plants had low colonization than *Rhizobium* and uninoculated control plants have very low. The present results are in line with those of Antunes *et al.* (2006) and Arumugam *et al.* (2010) who also reported spores, hyphae and arbuscules in noninoculated control plants.

The role of AMF in the tripartite symbiosis may be significant in soils with a low available P content (such as the soil used in this study) as nitrogen fixation is impaired by an inadequate P supply. Compatible AMF+*Rhizobium* treatments were probably due to enhanced nutrient uptake. Yield and P content increases have been shown to be significantly correlated with increases in the AMF colonization levels (Ibijbijen *et al.*, 1996). Valsalakumar *et al.* (2007) reported significant negative correlation was obtained between percentage colonization and P. The study indicates involvement of factors other than soil nutrients in the distribution and sporulation of AM fungi. Xiurong *et al.* (2010) reported that co-inoculation with rhizobia and AM fungi significantly increased soybean

growth and root colonization under low P and/or low N conditions as indicated by increased shoot dry weight.

Spore density when studied in summer and winter indicated that the dominant VA endophytes and plant species in each season were different following great variation. When spore number were high, the percentage colonization was low but as spore number began to decline the colonization increased. highest spore numbers were recorded from August to October while most mycorrhizal colonization recorded from December to March. Fluctuations in spore numbers have been attributed to seasonal variations (Hayman, 1970; Sutton & Barron, 1972). A variety of VAM fungi was found in both seasons *Glomus* species were found more frequently and this agree with the Valsalakumar *et al.* (2006), who observed that *Glomus mosseae* was the most frequent mycorrhizal associate; while *Scutellospora* was found only in one sample of *Vigna radiata*. In others case spores of *G. mosseae* and *Gigaspora margarita* were identified. The spore count in the latter species was very low. Valsalakumaret *al.* (2007) stated the correlations of spore count and percentage colonization for all the AM fungi on the crop in the field was related to soil parameters like pH, N, P, and K. The plants inoculated with individual treatment of AM fungi, rhizobium or RP and dual inoculation only shows positive for AM fungi colonization in roots. The *Rhizobium* inoculated plants, Rock phosphate and uninoculated control plants had very low root colonization and spore density as compared to the dual inoculated plants. Arumugam *et al.* (2010) observed high frequency of 96% of infection in roots of dual inoculated plants roots and 91% in AM fungi inoculated plants roots. Charitha & Reddy (2001) stated that dual inoculation of groundnut with rhizobium and VAM fungus resulted in significant increase in the mycorrhizal colonization, number of spores, growth parameters, i.e., fresh and dry weight, length of the root and shoot due to single inoculation or the uninoculated control. Combined inoculation of VAM fungi and *Rhizobium* and VAM + RP exhibited significant influence on root colonization and spore density of plant⁻¹ at all stages with maximum at flowering and at harvest at 15mg and 60mg application (Tables 18-32). It might be due to the synergistic effect of *Rhizobium* and VAM fungi on root colonization/development. (Kumutha *et al.*, 2004, Dudde & Raut, 2005). Rhizobium alone increased VAMF spores and infection but not so as compared to the combined inoculation (Tables

18-32). The finding of Ampofo (2008) indicated that *Rhizobium* inoculation reduced root colonization with all the *Glomus* species except *Gigaspora rosea*. A highly significant ($P < 0.001$) interaction between mycorrhiza and *Rhizobium* was observed for mycorrhiza root colonization. *Glomus* spp. are higher than *sclerocystis* and *Acaulospora*, respectively at all growth phases. However, Rhz.+VAM and VAM+RP generally enhanced their density which were various from cultivar to cultivar (Tables 18-32). The result agrees with Maya *et al.* (2010) that percent VAM infection was recorded in combination of *Rhizobium* and VAM inoculation i.e. T4 when compared to T1 (control), T2 (*Rhizobium*) and T3 (*Glomus fasciculatum*). And similarly Valsalakumar *et al.* (2007) reported that rhizosphere soil samples were analyzed for AM fungal spores. *Glomus mosseae*, *Glomus microcarpum*, *Gigaspora margarita* and *Scutellospora* sp. were identified as the AM fungi associated with green gram. *Glomus* spp. was the most frequent AM fungal associate identified in 81%, *G. microcarpum* and *G. margarita* in 24% each, and *Scutellospora* sp. in 5% of the soils studied. The range of distribution varied from a single species of AM fungus to three species belonging to two genera in one sample. This agrees with the finding of Ampofo (2008), who inoculated plants with *Glomus clarum* and *Glomus intraradices* that significantly achieved higher root colonization than *Glomus etunicatum* and *Gigaspora rosea*. In some cases VAM +Rhz. declined the density of spores and result agrees with Ray & Valsalakumar (2010), who reported that analysis of spore count in post harvest soil species of *Glomus* behaved differentially due to various treatments. It was observed that there was a general tendency for *Glomus* to reduce sporulation in presence of the *Rhizobium*. Hani (2009) observed VAM infection improved plant survival and growth by enhancing the root's ability to absorb moisture, macro-nutrients and micro-nutrients from the soil. There are several benefits of AMF colonization in plants, mainly the increase in nutrient uptake (Smith & Read, 2008). RP has significant positive influence on spore density of AMF on roots in *Vigna radiata* L., *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris*.

This observation agrees with that of the use of phosphate solubilizing microorganisms, including arbuscular mycorrhizal (AM) fungi, has been proposed as a low-cost and low-energy mechanism to help increase the agronomic effectiveness of RP fertilizers (Richardson, 2001; Gyaneshwar *et al.*, 2002). RP alone have less effect on

spore density than when combine with VAM as presented in (Tables 18-32)agree with the interactions between P solubilizing bacteria and AM fungi in the mobilization of P from RP and effect on VAM infection have been consistently reported (Barea *et al.*, 1975, 2002; Toro *et al.*, 1997; Caravaca *et al.*, 2004; Cabello *et al.*, 2005;Antunes *et al.*, 2006).

There is a specificity of VAM and rhizobium ,natural diversity in the soil of AM fungi different from species to species and differently influence root colonization and spore density of studied legumes at all stages as shown in (Tables 18-32).Similarly specific bacterial strains promote germination of AM fungal spores and can increase the rate and extent of root colonization by AM. Johansson *et al.* (2004) also Geneva *et al.* (2006) the rate of mycorrhizal . Xavier & Germida (2002)observed that AMF and rhizobia are compatible with each other and with the host plant, the growth, yield, and infection of lentil can be significantly enhanced even in non-sterile soil containing indigenous AMF and rhizobia also noted that co-inoculation with one AMF species significantly increased plant productivity over the other for the same *Rhizobium* strain or isolate, irrespective of its effectiveness on the host. Therefore, it is crucial to consider compatibility between *Rhizobium* strains and the AMF community not only for enhanced productivity, but also for the enhanced survival and establishment of legumes growing in less than ideal environmental conditions.The deep root Mungbean had greater AMF colonization at low P. Mungbean have deep roots than lentil due to which they have more colonization compared to lentil.These are supported by Xiurong *et al.*(2010), who reported that Furthermore, the effects of co-inoculation were related to root architecture. AM fungal colonization influences root architecture of the host plant in most studies by causing a more profusely branched root system (Price *et al.*, 1989; Yano *et al.*, 1996; Paszkowski *et al.*, 2002; Olah *et al.*, 2005; Gutjahr *et al.*, 2009).Growth wise mungbean, followed by burgundy,pea lentil and desmodium plants as in tables, Influence of AM in enhancing the growth and yield of a crop depends on the percent colonization of AM fungi on roots of the crop (Zhu *et al.*, 2003).The increase in plant growth may be attributed to increased uptake of phosphorus by VAM fungus, which increase the activity of root nodule bacteria as also reported by (Mytton & Livesey 1983;Charitha & Reddy, 2001).It is evident from our study that the maximum number of arbuscules, vesicles and

spores in dual inoculated plants may be due to the fact that both VAM fungus and *Rhizobium* are active in root cortical cells. That means the presence of one symbiont may be influencing the activity of the other as also suggested by Vejsadova *et al.* (1992) in Soybean.

The results of the present study (Tables 18-32).revealed the maximum number of *Glomus* species in the soils of studied plants i.e., *Glomus fasciculatum*, *Glomus aggregatum*, root colonization by *Glomus* spp. with more arbuscules and vesicles than sclerocystis and *Acaulospora*Fig.(35-38) . Our findings corroborate with the finding of Hart & Reader, 2002; Ampofo , 2008; Fatma *et al.*, 2009) that genus *Glomus* is a predominantly distributed genus in the soil all over the world and was most efficient and produced statistically higher mycorrhizal colonization than other mycorrhizal fungi also agree with the report of Abdulla& Khaliel (2010), who stated the influence of AM fungi on growth indices revealed that *G. mosseae* was the more effective fungus in stimulating peanut growth when compared with *G. fasciculatum*. Similarly correlate with the finding of Pande & Tarafdar (2004) who reported that predominance of *Glomus* species under varying soil conditions might be due to the fact that they are widely adaptable to the varied soil conditions and survive in acidic as well as in alkaline soils. The *Acaulospora* are detected in very trace amount in all studied plants (Tables 18-32).Our results agree with Boddington & Dodd (2000) that absence of detectable root-colonization by *Acaulospora* could be due to incompatibility with common beans, or difficult staining of the root-colonization structures.

Table 18. (Vesicular-) arbuscular mycorrhizal spores density in *Vigna radiate* at vegetative stage.

Varieties	Treatments	VAMF spores density		
		<i>Gl1</i>	<i>Scl1</i>	<i>Ac1</i>
Niab-92 V ₁ *	Control	60.33±2.36	10.33±1.58	2.00±0.88
	VAM	71.67±1.26	10.67±2.04	5.33±0.69
	Rhz	70.33±4.40	10.0±1.53	5.0±0.33
	VAM+Rhz	78.0±0.33	11.0±1.00	4.33±0.38
	RP ₁	56.67±3.47	5.00±1.45	1.33±0.19
	MRP ₁	56.67±3.47	6.00±1.20	2.33±0.19
	MRP ₂	63.67±3.95	7.33±1.35	3.67±0.77
Niab-98 V ₂ **	Control	45±1.67	8.33±0.96	2.33±0.51
	VAM	76.67±5.77	11.67±2.89	3.33±3.51
	Rhz	60.67±2.01	10.67±1.50	2.33±0.19
	VAM+Rhz	86.33±5.51	13±2	3.00±1
	RP ₁	76±1.76	8±0.67	2±0.58
	MRP ₁	63.67±3.95	7.33±1.35	3.67±0.77
	MRP ₂	77±1.73	9.33±1.35	2.33±0.19
Niab-2006V ₃ ***	Control	53.67±1.17	9±0.88	2.67±0.19
	VAM	86.67±0.69	14.33±0.84	4±0.33
	Rhz	75±1.45	14±0.88	2.67±0.51
	VAM+Rhz	96.67±0.84	15.67±0.51	0.67±0.19
	RP ₁	82.67±2.14	8.67±1.02	2.67±0.51
	MRP ₁	77.67±1.95	10±1.67	2.33±0.19
	MRP ₂	93.67±1.07	8.33±0.96	4.33±1.02

All values mean ± SEM of 3 determinations (replicates)

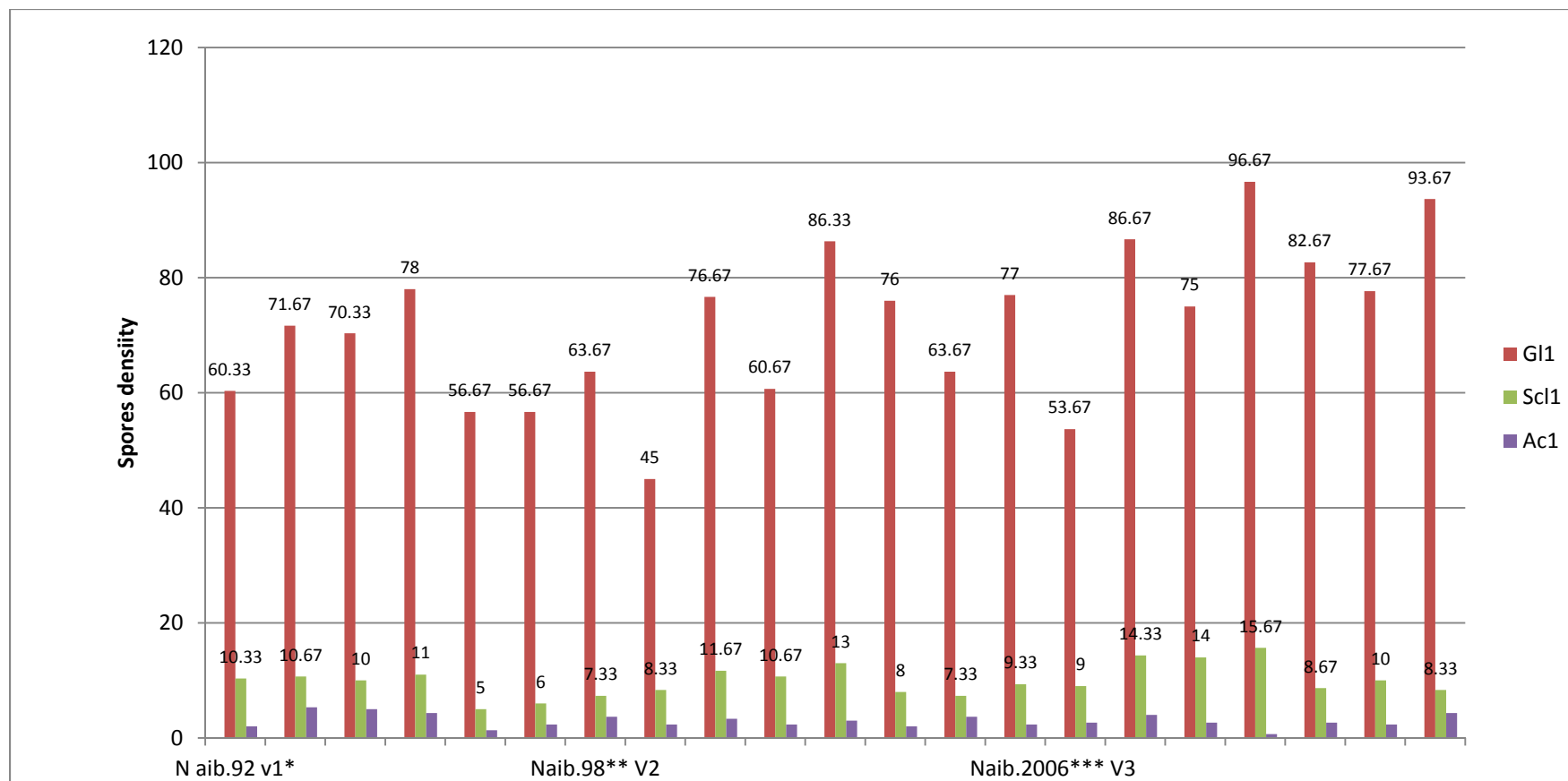


Fig.18. (Vesicular-) arbuscular mycorrhizal spores density in *Vigna radiata* at vegetative stage.

Table 19. (Vesicular-) arbuscular mycorrhizal spores density in *Vigna radiata* at flowering stage.

Varieties	Treatments	VAMF spores density		
		<i>Gl2</i>	<i>Scl2</i>	<i>Ac2</i>
Niab-92 V₁*	Control	64.33±1.58	10.33±0.51	3.33±0.19
	VAM	73.00±1.20	9.67±0.51	2.67±0.69
	Rhz	71.0±.33	6.67±0.96	3.67±0.51
	VAM+Rhz	81.33±1.92	13.67±1.90	4.33±0.38
	RP₁	66.67±2.55	3.67±0.51	1.33±0.51
	MRP₁	68.33±1.92	4.00±0.33	3.00±0.67
	MRP₂	72.00±2.52	6.67±1.02	2.00±0.33
Niab-98 V₂**	Control	53.67±0.51	5±0.33	1.33±.19
	VAM	81.33±8.14	11.67±2.08	3.33±1.53
	Rhz	66±1.76	11.67±0.96	4.33±0.38
	VAM+Rhz	89.33±4.04	12±2.65	3.33±1.53
	RP₁	81.33±0.51	7.33±0.69	1.67±0.19
	MRP₁	72±2.52	6.67±1.02	2±0.33
	MRP₂	79±1.20	9.33±0.51	2.33±0.38
Niab-2006V₃***	Control	63.33±1.39	8.67±0.19	3±0.33
	VAM	89.67±0.19	14.67±0.51	2.33±0.19
	Rhz	81.67±0.69	12.33±0.51	0.67±0.19
	VAM+Rhz	100.33±3.3	13.67±1.84	3.67±0.51
	RP₁	84.67±1.58	8.67±1.35	2.67±0.19
	MRP₁	79±1.20	12±1.20	2.33±0.38
	MRP₂	90±5.49	5±0.33	1.33±0.19

All values mean ± SEM of 3 determinations (replicates)

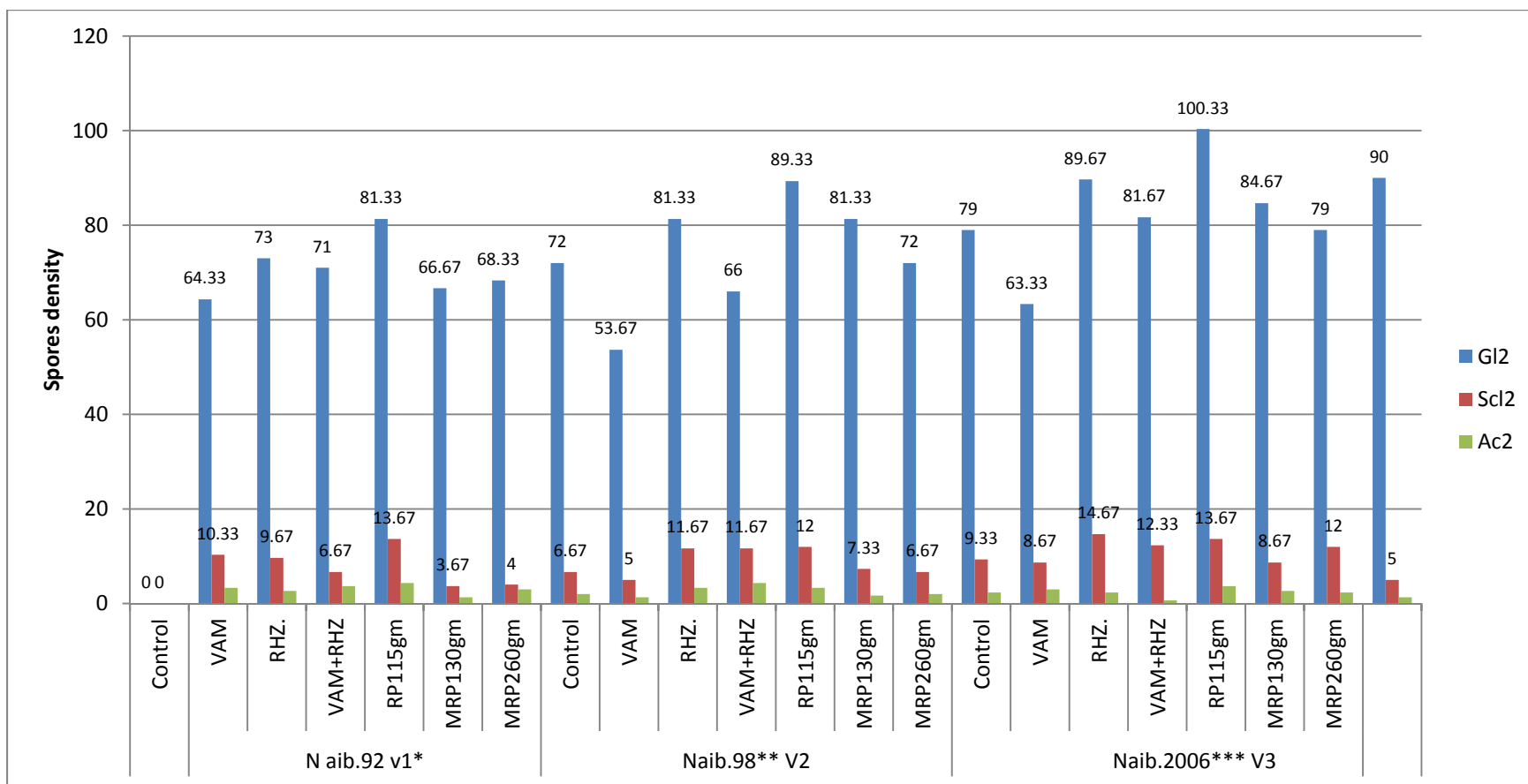


Fig. 19.(Vesicular-) arbuscular mycorrhizal spores density in *Vigna radiata* atflowering stage.

Table 20. (Vesicular-) arbuscular mycorrhizal spores density in *Vigna radiata* at fruiting stage.

Varieties	Treatments	VAMF spores density		
		<i>Gl3</i>	<i>Scl3</i>	<i>Ac3</i>
Niab-92 V ₁ *	Control	73.00±2.96	10.33±0.19	2.33±0.19
	VAM	80.00±0.88	10.00±0.33	3.33±0.19
	Rhz	75.0±1.45	8.33±0.69	3.67±0.51
	VAM+Rhz	90.0±2.40	9.33±0.51	3.67±0.51
	RP ₁	70.00±0.00	4.33±0.77	2.33±0.19
	MRP ₁	72.33±0.84	4.33±0.77	2.33±0.19
	MRP ₂	73.00±1.20	7.00±0.88	2.67±0.38
Niab-98 V ₂ **	Control	60±0.33	3.67±0.51	1.33±0.19
	VAM	84.33±5.69	9.67±0.58	3.33±0.58
	Rhz	77±2.33	9.33±0.38	2.33±0.19
	VAM+Rhz	93.00±3.00	13.33±3.06	3.67±0.58
	RP ₁	63.67±15.7	8±1.45	2.67±0.19
	MRP ₁	73±1.20	7±0.88	2.67±0.38
	MRP ₂	90.67±0.69	7.33±1.02	2.33±0.51
Niab-2006V ₃ ***	Control	72±0.88	8.67±0.69	1.67±0.51
	VAM	96.33±1.58	12.67±0.69	4.67±0.69
	Rhz	90±3.33	9.33±0.38	3.67±0.84
	VAM+Rhz	103±4.18	16±0.33	5±0.33
	RP ₁	67.33±16.0	9.67±0.51	2.67±0.19
	MRP ₁	81±2.19	7.33±1.02	2.33±0.51
	MRP ₂	98.33±4.19	11.67±0.96	2±0.58

All values mean ± SEM of 3 determinations (replicates)

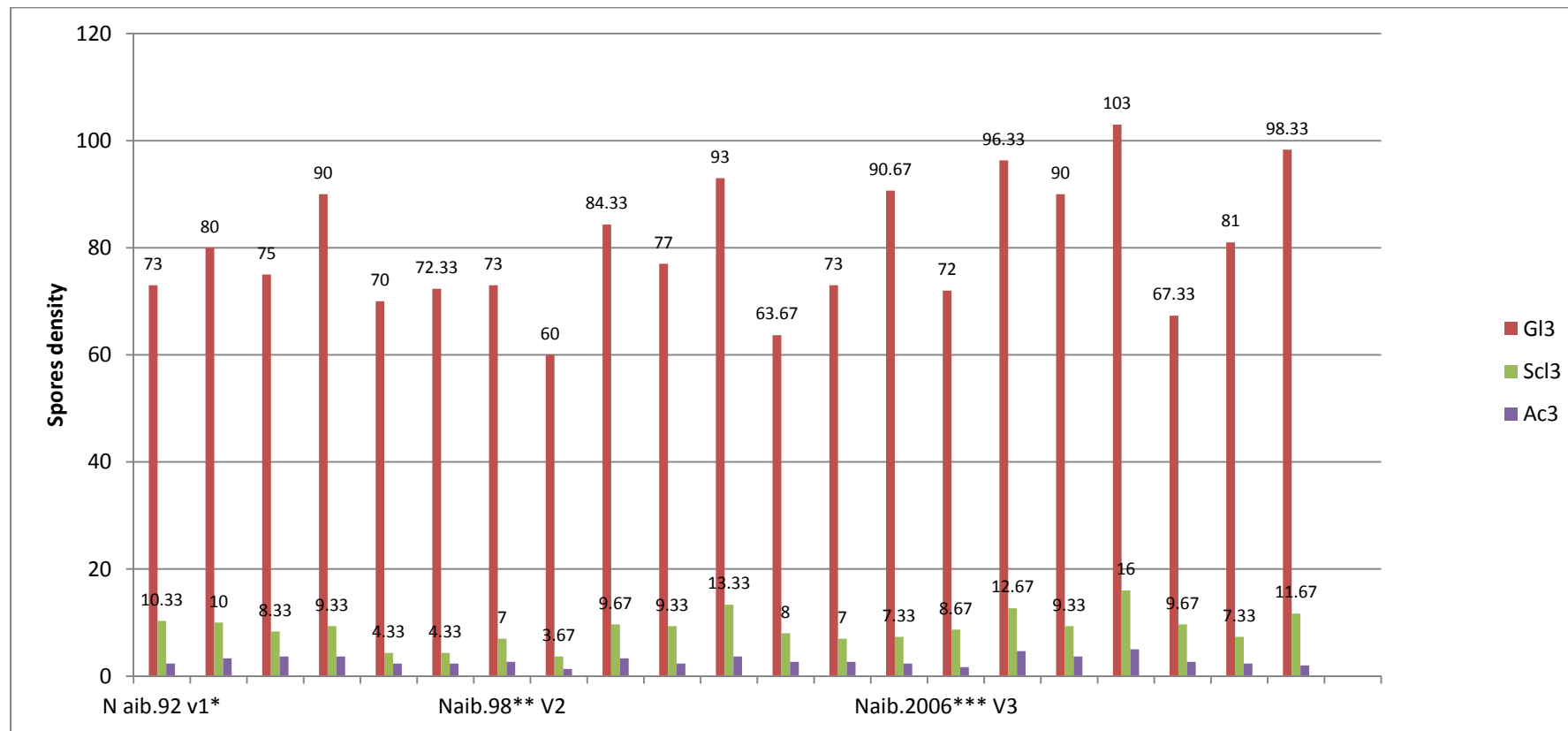


Fig. 20.(Vesicular-) arbuscular mycorrhizal spores density in *Vigna radiata* at fruiting stages.

Table 21. Vesicular-) arbuscular mycorrhizal spores density in *Macroptilum bracteatum* at vegetative stage.

Treatments	VAMF spores density		
	<i>Gl1</i>	<i>Scl1</i>	<i>Ac1</i>
Cont.	38.67±3.37	7.33±0.77	2±0.33
VAM	78.67±0.51	11.67±1.58	4±0.33
Rhz	70±0.00	11±0.33	2.67±0.19
VAM+Rhz	88±0.33	12.76±0.69	5.33±0.19
RP₁	42±0.67	6.33±1.17	2.33±0.19
MRP₁	50±0.67	4.33±0.51	1.67±0.38
MRP₂	66.00±2.52	10.60±0.56	2.56±0.19

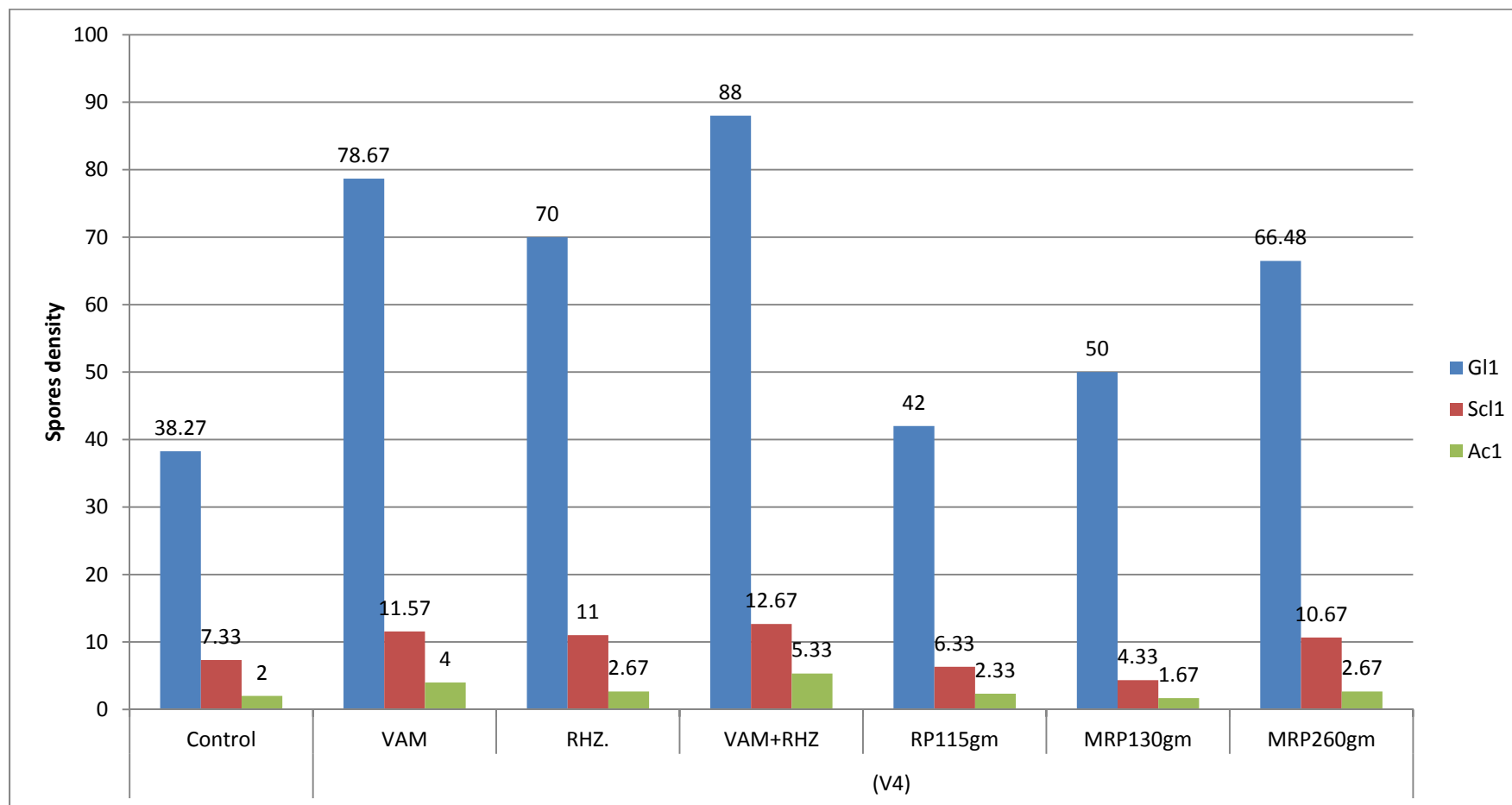


Fig. 21. Vesicular-) arbuscular mycorrhizal spores density in *Macropitulum bracteatum* at vegetative stage.

Table 22. Vesicular-) arbuscular mycorrhizal spores density in *Macropitulum bracteatum* at flowering stage.

Treatments	VAMF spores density		
	<i>Gl2</i>	<i>Scl2</i>	<i>Ac2</i>
Cont.	47.33±0.84	4±0.33	2.33±0.19
VAM	79.67±0.19	9.33±0.51	1±0.33
Rhz	75±2.08	8.67±1.64	3±0.33
VAM+Rhz	93.33±.96	10±0.51	2.67±0.51
RP₁	49±1	6.67±1.68	3±0.33
MRP₁	57±1.20	5±0.33	2.67±0.19
MRP₂	71.47±1.53	8.47±1.46	3±0.33

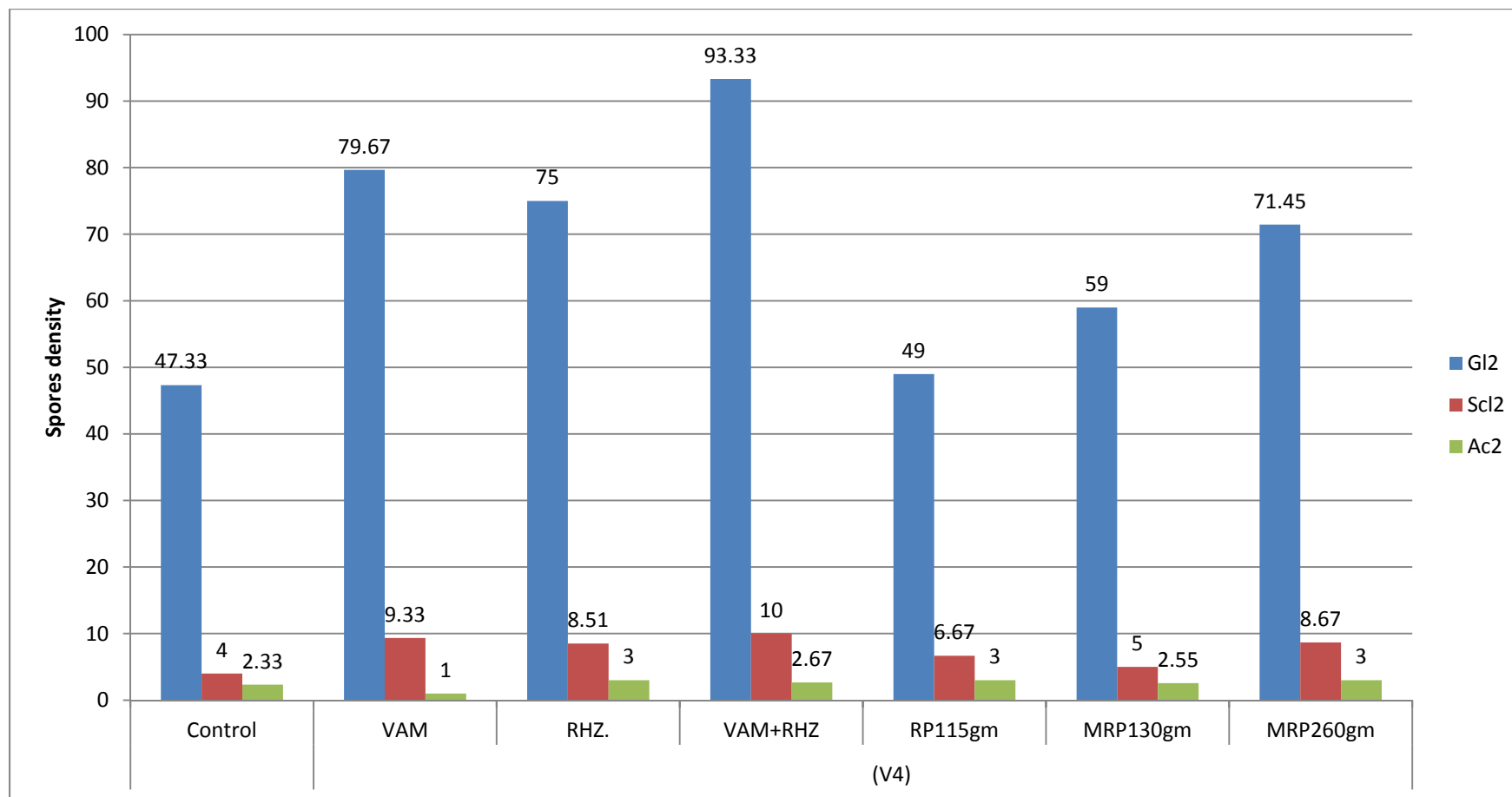


Fig.22.Vesicular-) arbuscular mycorrhizal spores density in *Macroptilum bracteatum* at flowering stage.

Table 23. Vesicular-) arbuscular mycorrhizal spores density in *Macroptilum bracteatum* at fruiting stage.

Treatments	VAMF spores density		
	<i>Gl3</i>	<i>Scl3</i>	<i>Ac3</i>
Cont.	56.67±0.69	5±0.33	3.67±0.69
VAM	89±0.33	8.67±0.38	3±0.33
Rhz	82±0.67	12±1	5.67±0.69
VAM+Rhz	89.33±0.38	9.33±0.38	3.67±0.69
RP₁	57.33±2.36	5.33±0.51	1.67±0.19
MRP₁	59.33±0.69	4.67±0.51	2±0.23
MRP₂	82±0.57	9.32±1.12	1.59±0.20

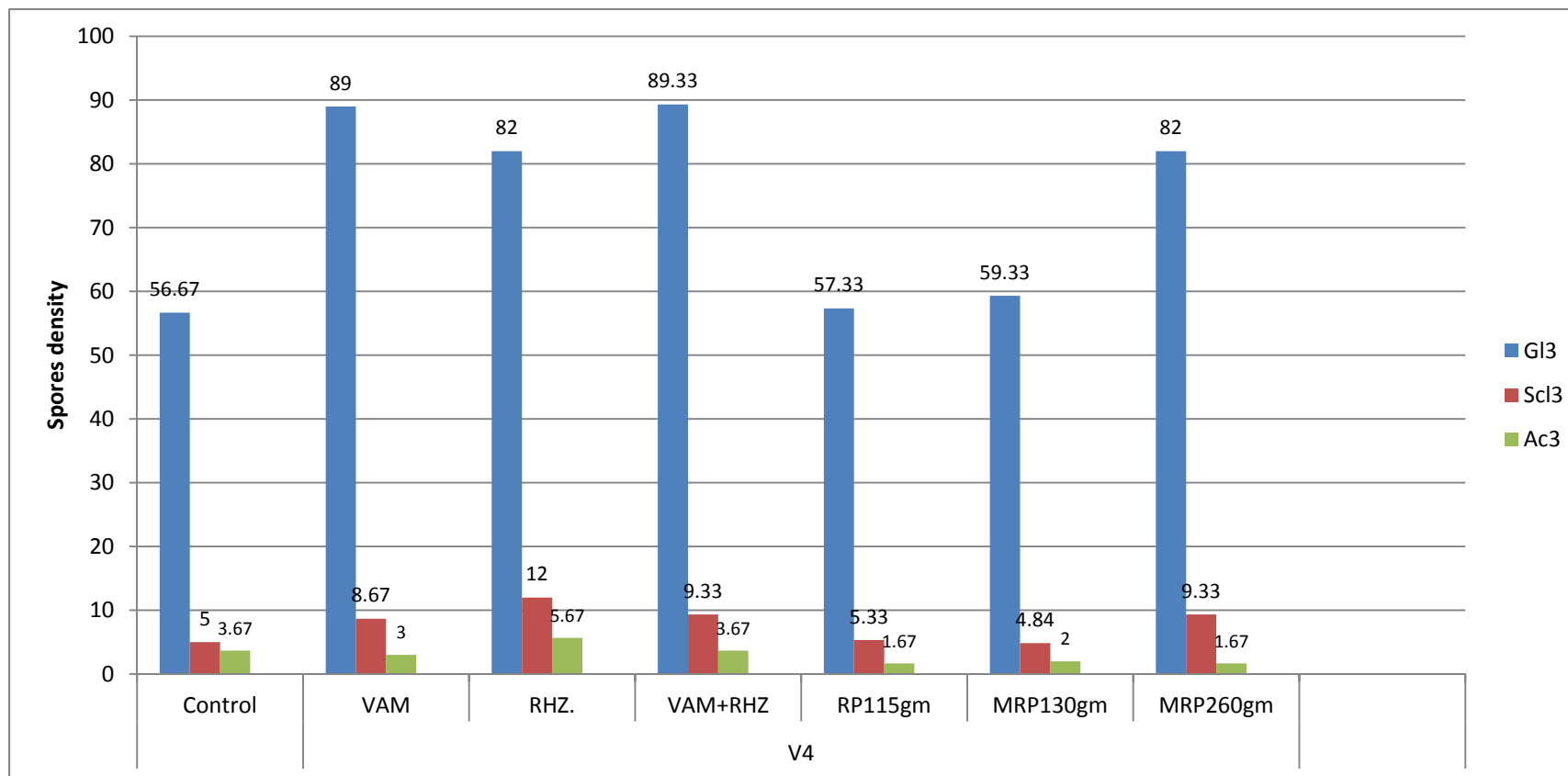


Fig.23. Vesicular-) arbuscular mycorrhizal spores density in *Macroptilum bracteatum* at fruiting stage.

Table 24. (Vesicular-) arbuscular mycorrhizal spores density in *Pisum sativum* at vegetative stage.

Treatments	VAMF spores density		
	<i>Gl1</i>	<i>Scl1</i>	<i>Ac1</i>
Control	29.67±0.84	5±0.33	1±0.33
VAM	51.33±1.07	7.33±1.17	2.00±0.33
Rhz	51.67±1.17	4.67±0.19	3.00±0.88
VAM+Rhz	53.33±0.96	8.67±1.26	2.67±0.38
RP₁	33.00±0.67	5.33±0.69	2.33±0.19
MRP₁	44.33±0.19	4.33±0.51	1.67±0.38
MRP₂	50.00±0.67	4.33±0.45	1.67±0.51

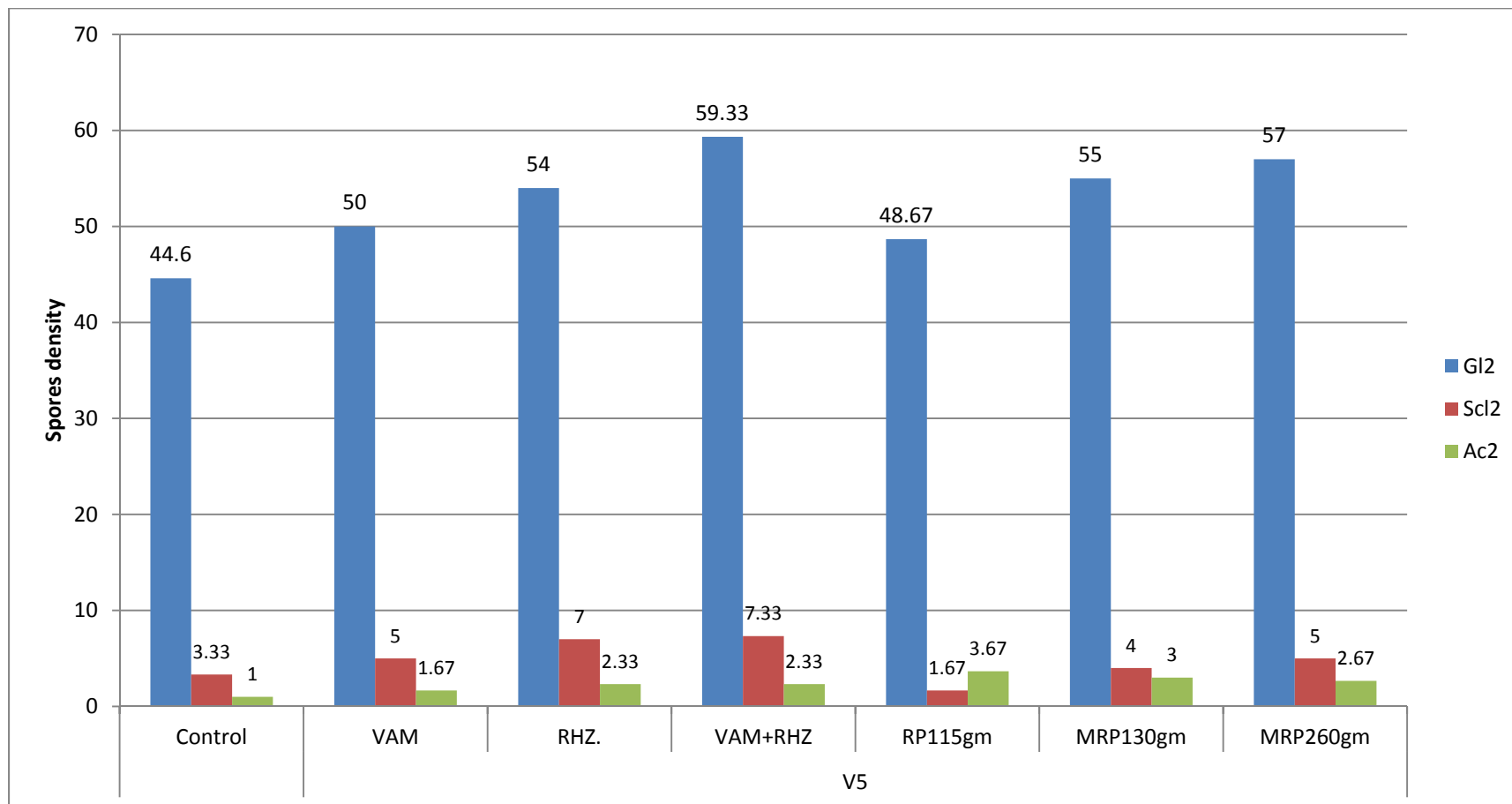


Fig.24.(Vesicular-) arbuscular mycorrhizal spores density in *Pisum sativum* at vegetative stage.

Table 25. (Vesicular-) arbuscular mycorrhizal spores density in *Pisum sativum* at flowering stage.

Treatments	VAMF spores density		
	<i>Gl2</i>	<i>Scl2</i>	<i>Ac2</i>
Control	44.67±1.50	3.33±0.33	1±0.33
VAM	50.00±0.33	5.00±0.88	1.67±0.19
Rhz	54.00±0.67	7.00±0.33	2.33±0.19
VAM+Rhz	59.33±1.50	7.33±1.39	2.33±0.19
RP₁	48.67±0.38	1.67±0.96	3.67±0.19
MRP₁	55.00±0.67	4.00±0.33	3.00±0.33
MRP₂	57.00±1.07	5.00±1.20	2.67±0.33

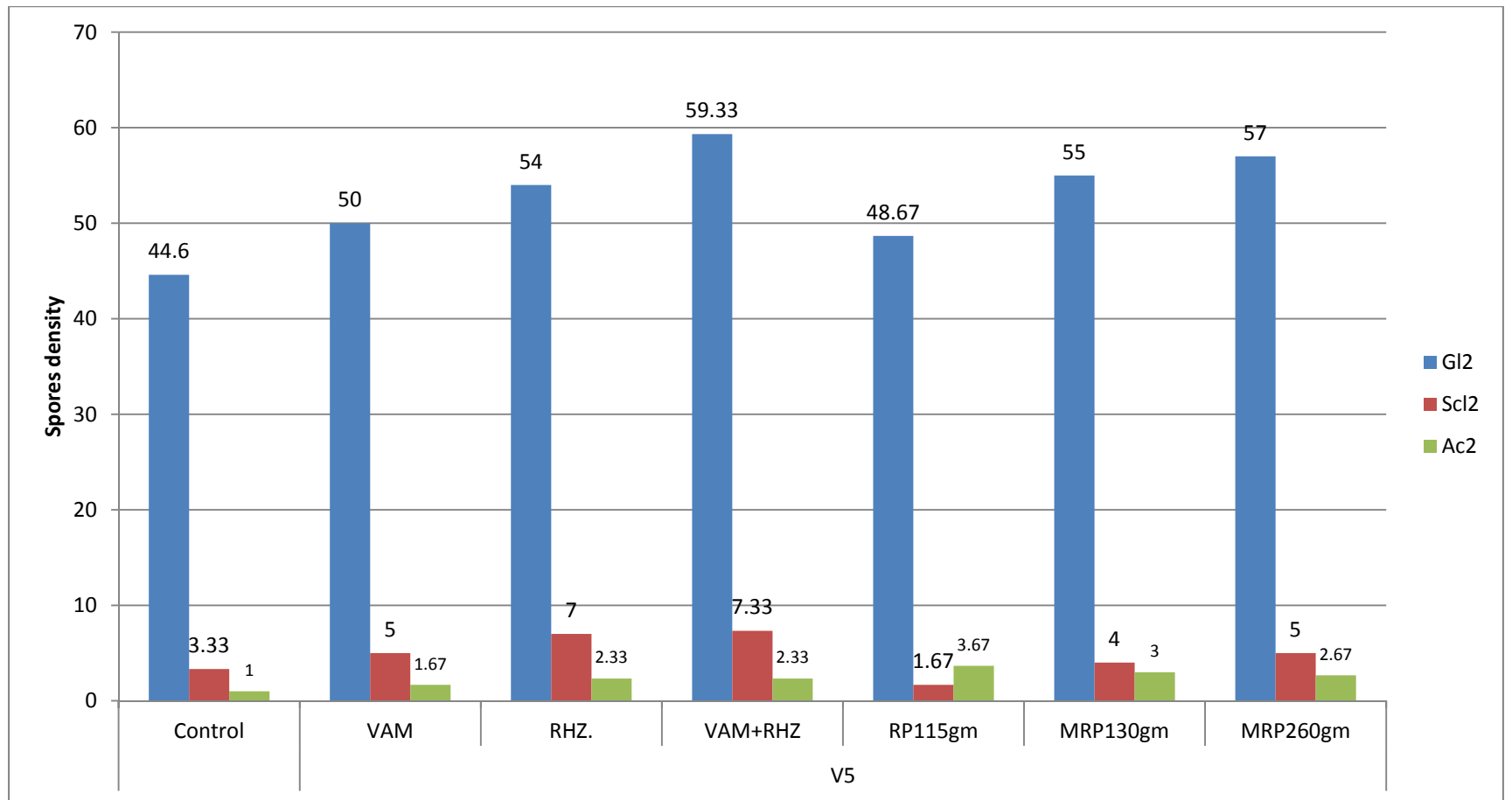


Fig.25.(Vesicular-) arbuscular mycorrhizal spores density in *Pisum sativum* atf lowering stage.

Table 26. (Vesicular-) arbuscular mycorrhizal spores density in *Pisum sativum* at fruiting stage.

Treatments	VAMF spores density		
	<i>Gl3</i>	<i>Scl3</i>	<i>Ac3</i>
Control	46.67±1.26	2.67±0.38	1.33±0.1
VAM	60±5.04	7.33±2.14	1.67±0.19
Rhz	68.33±3.56	6.67±0.38	1.00±0.58
VAM+Rhz	71±1.45	8.33±1.58	2.67±0.19
RP₁	52.00±0.33	4.00±0.33	1.67±0.51
MRP₁	59.33±0.69	4.67±0.51	2.00±0.33
MRP₂	59.33±0.84	4.67±0.69	2.00±0.33

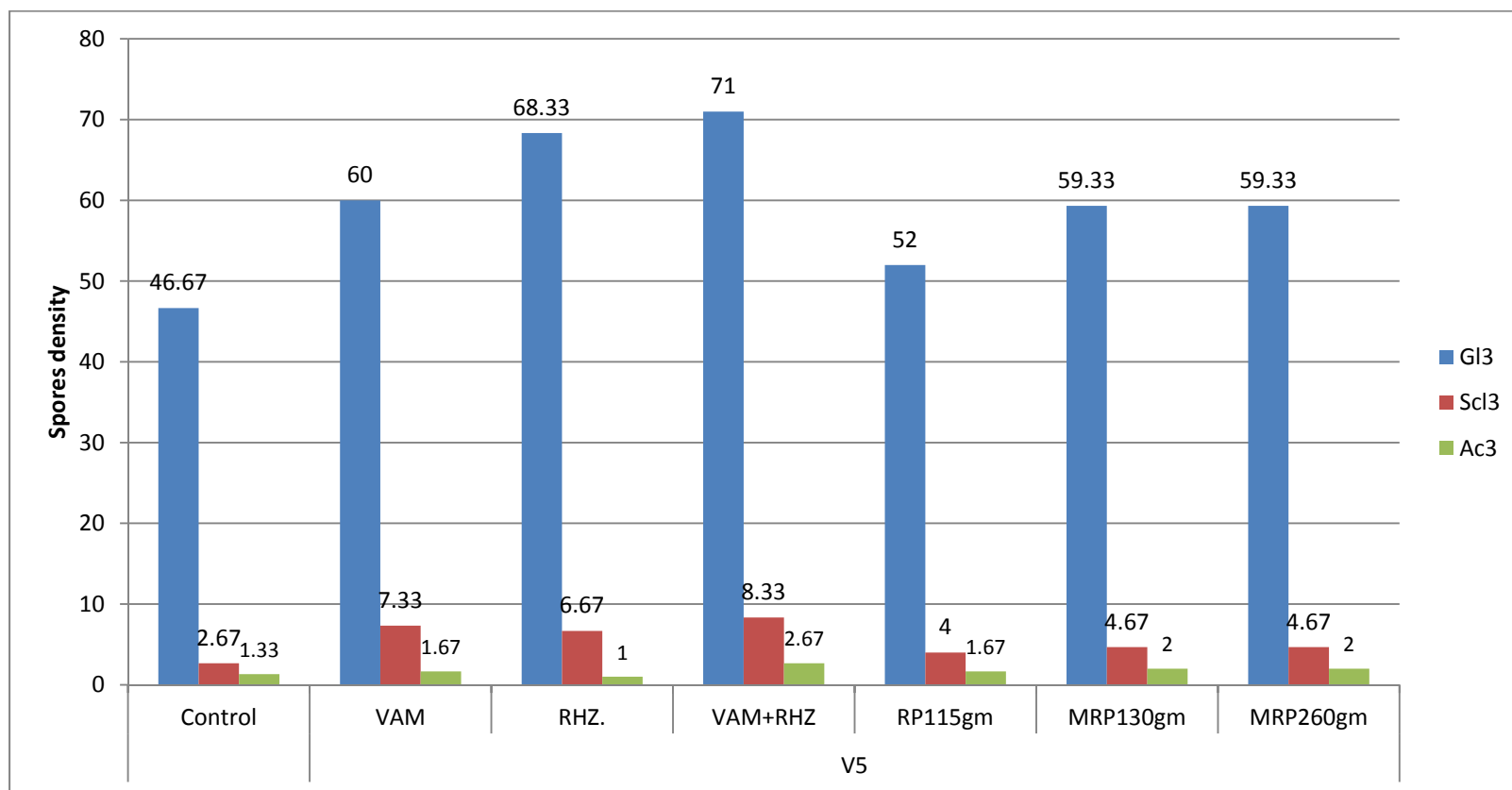


Fig. 26.(Vesicular-) arbuscular mycorrhizal spores density in *Pisum sativum* at fruiting stage.

Table 27.(Vesicular-) arbuscular mycorrhizal spores density in *Desmodium adscendens* at vegetative stage.

Treatments	VAMF spores density		
	<i>Gl1</i>	<i>Scl1</i>	<i>Ac1</i>
Control	51.33±1.39	9.67±1.17	4.33±0.19
VAM	82.60±1.84	12±2.33	3.33±0.69
Rhz	78.33±2.87	13.67±0.51	4±0.00
VAM+Rhz	88±0.33	12.68±0.69	5.33±0.19
RP₁	51±1.45	10±0.33	2.33±0.19
MRP₁	58±2.41	9.67±1.07	2.67±0.19
MRP₂	66.67±2.52	10.67±0.51	2.67±0.19

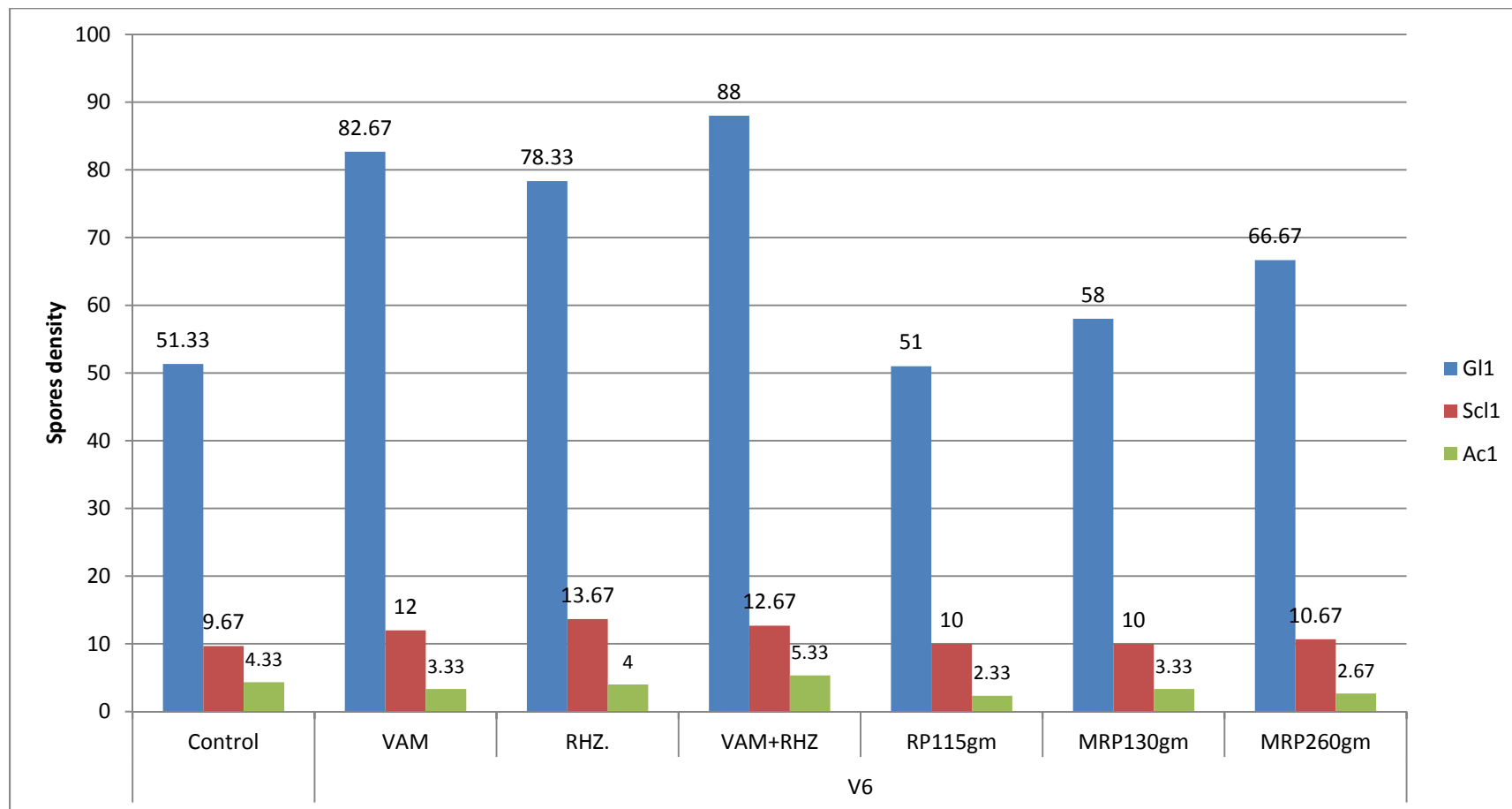


Fig.27. (Vesicular-) arbuscular mycorrhizal spores density in *Desmodium adscendens* at vegetative stage.

Table 28.(-Vesicular-) arbuscular mycorrhizal spores density in *Desmodium adscendens* at flowering stage.

Treatments	VAMF spores density		
	<i>Gl2</i>	<i>Scl2</i>	<i>Ac2</i>
Control	51.67±2.55	6±1.20	2.33±0.19
VAM	81.66±0.96	8.53±0.19	2±0.76
Rhz	82.67±1.26	9.33±0.51	3±0.58
VAM+Rhz	93.33±0.96	10±0.88	2.67±0.51
RP₁	61±0.88	10±0.88	2.63±0.19
MRP₁	63.61±0.77	5±0.00	2.67±0.19
MRP₂	71.667±1.58	8.67±1.64	3±0.34

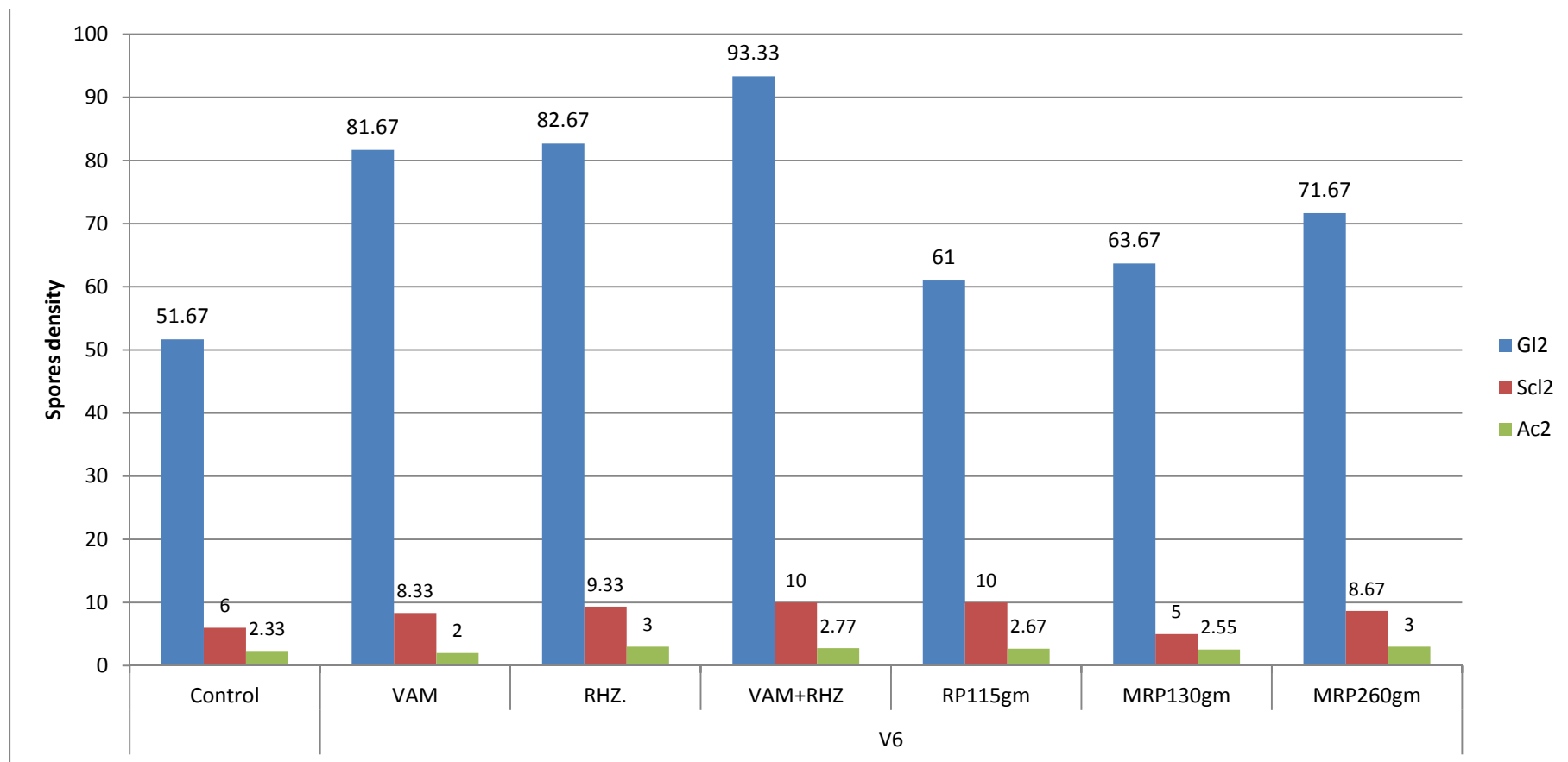


Fig.28. Vesicular-) arbuscular mycorrhizal spores density in *Desmodium adscendens* at flowering stage.

Table 29.(Vesicular-) arbuscular mycorrhizal spores density in *Desmodium adscendens* at fruiting stage.

Treatments	VAMF spores density		
	<i>Gl3</i>	<i>Scl3</i>	<i>Ac3</i>
Control	59±1	8.67±1.17	2.67±0.51
VAM	89±0.33	12±2.13	2.56±0.38
Rhz	86.66±1.92	13.67±1.90	3.67±0.51
VAM+Rhz	89.33±0.38	14.33±2.01	3.67±0.69
RP₁	63.32±0.97	7.33±1.02	3.22±0.38
MRP₁	76.32±1.84	6.33±1.90	5±0.88
MRP₂	82±0.67	9.33±1.02	1.67±0.19

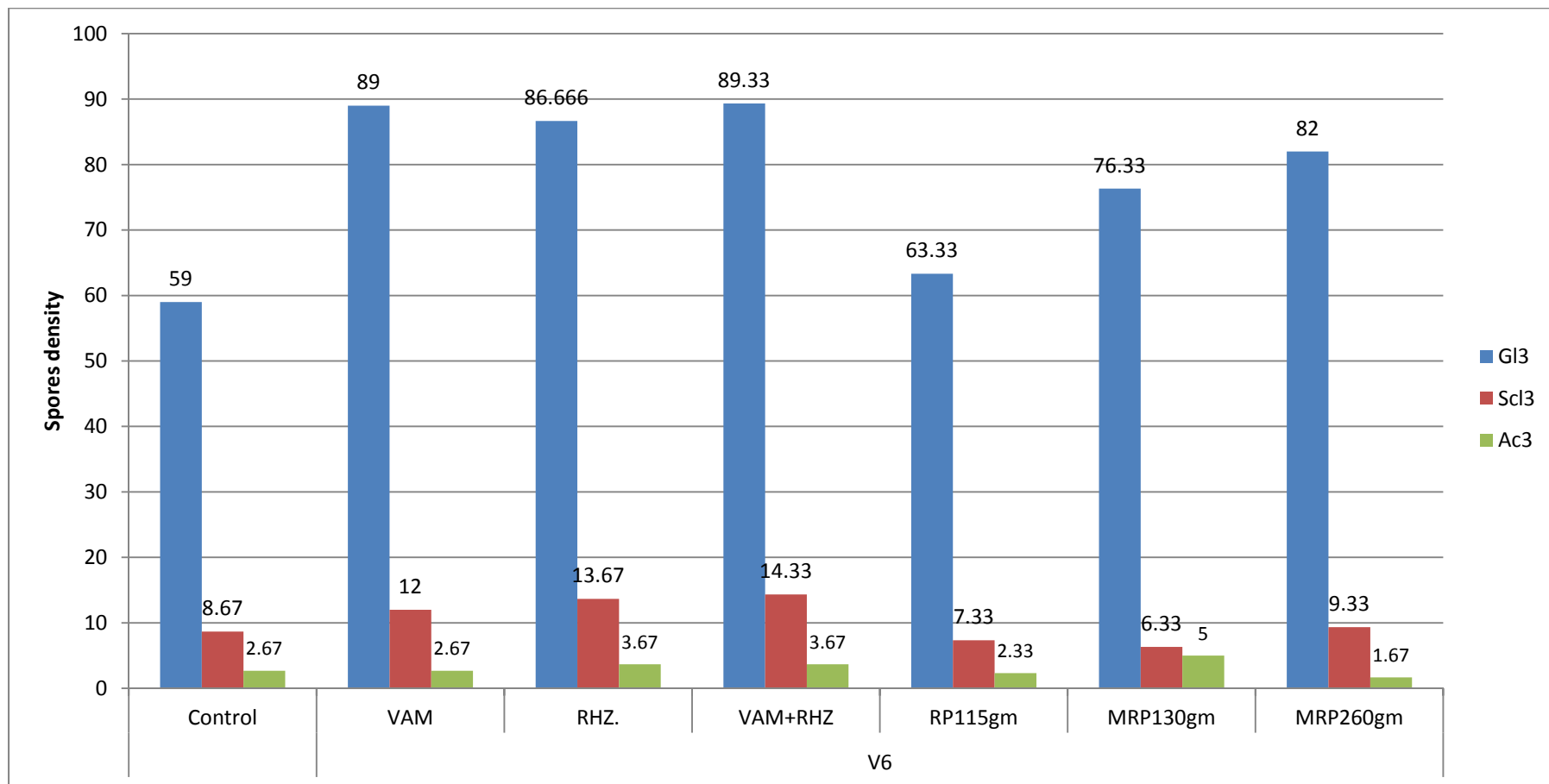


Fig. 29.(Vesicular-) arbuscular mycorrhizal spores density in *Desmodium adscendens* at fruiting stage.

Table 30. Vesicular-) arbuscular mycorrhizal spores density in *Lens culinaris* (V₇-V₁₀) at vegetative stage.

Varieties	Treatments	VAMF spores density		
		<i>Gl1</i>	<i>Scl1</i>	<i>Ac1</i>
NARC-2002 V ₇ **	Cont.	64.33±1.64	8.67±0.77	1±0.33
	VAM	91.33±2.31	14.67±5.03	5.33±1.53
	Rhz	82±1.45	14±1.20	4±3.67
	VAM+Rhz	102.66±8.14	15.67±4.51	6.67±3.21
	RP ₁	85±1.53	10±0.67	6.67±0.69
	MRP ₁	84±6.96	11.33±0.84	9±0.33
	MRP ₂	104±2.91	11.33±0.38	4.67±0.84
NARC-2008-3 V ₈ *	Cont.	57.13±0.77	7.65±0.84	2.67±0.16
	VAM	83.46±5.52	10±1.00	3.64±0.58
	Rhz	74±1.76	12±0.58	3.67±0.19
	VAM+Rhz	93.33±5.77	12.67±2.52	5.67±0.58
	RP ₁	71.67±0.96	7.33±0.77	3.33±0.38
	MRP ₁	73.33±3.85	9.33±0.69	6.33±0.84
	MRP ₂	103.33±2.5	10.67±0.38	3.67±0.51
NARC-2008-4 *** V ₉	Cont.	56.67±1.92	10±0.00	5±0.33
	VAM	107.67±5.8	19.33±2.08	6.33±0.58
	Rhz	111±3.51	14±1.20	9.67±0.51
	VAM+Rhz	128±4.67	20.67±0.19	9.33±0.51
	RP ₁	127±1.67	21.33±0.69	10.33±0.5
	MRP ₁	129.33±4.3	21±2.33	12±1.73
	MRP ₂	132.33±4.1	23.33±2.46	14±1.73
NARC-2002 V ₁₀ ****	Cont.	75±2.89	8.67±1.07	5±0.33
	VAM	119.33±2.0	21±1.00	6.67±1.53
	Rhz	120.67±1.7	12±0.88	9.67±0.51
	VAM+Rhz	151±2.65	33.33±1.92	16.67±0.6
	RP ₁	134.33±2.9	21.33±0.69	10.33±0.5
	MRP ₁	149.67±0.5	30.33±2.99	14.33±1.9
	MRP ₂	144.67±1.5	17±2.03	8.33±1.02

All values mean ± SEM of 3 determinations (replicates)

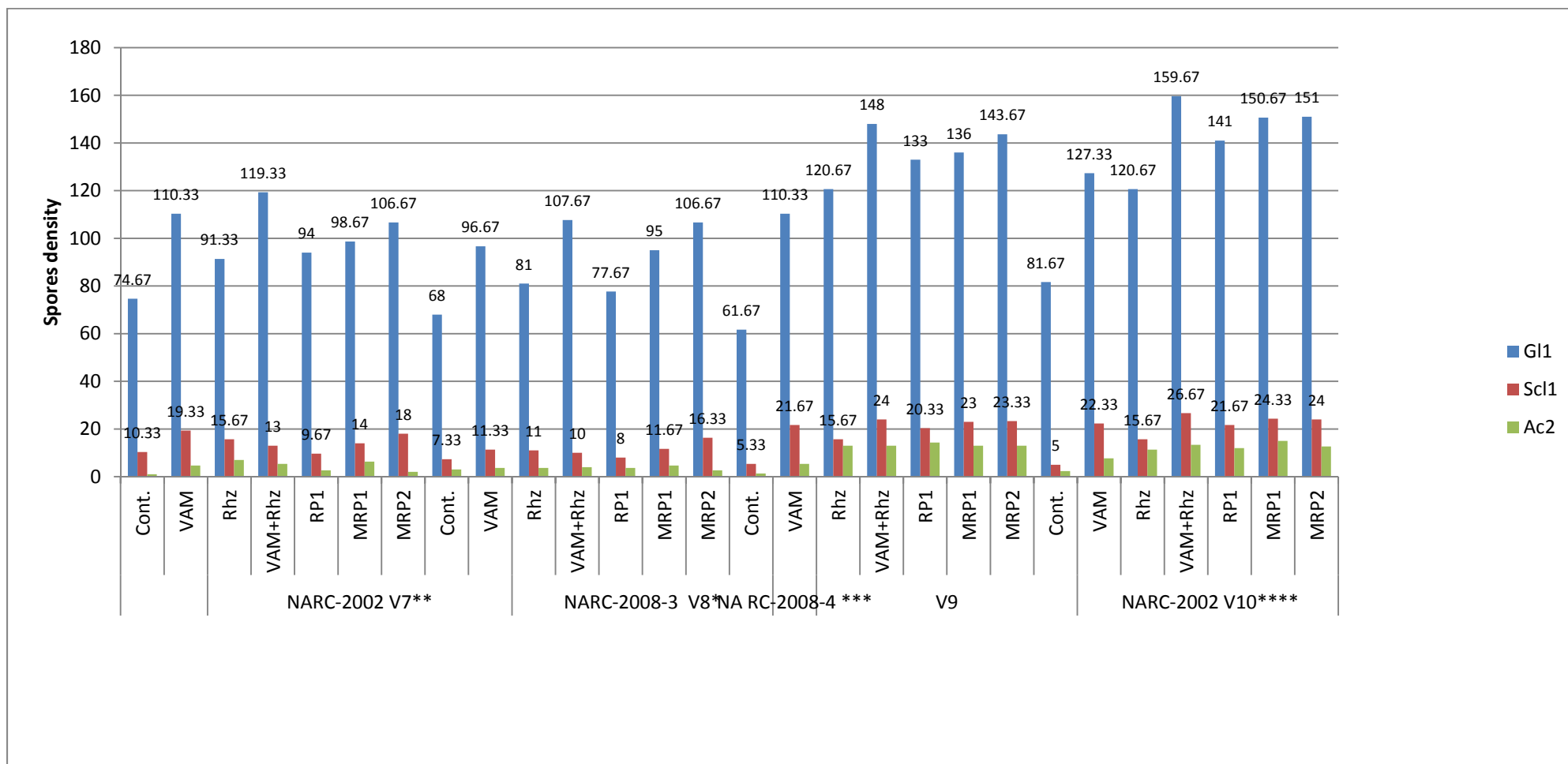


Fig.30. (Vesicular-) arbuscular mycorrhizal spores density in *Lens culinaris* (V₇-V₁₀) at vegetative stage.

Table 31. Vesicular-) arbuscular mycorrhizal spores density in *Lens culinaris* (V₇-V₁₀) at flowering stage.

Varieties	Treatments	VAMF spores density		
		<i>Gl2</i>	<i>ScI2</i>	<i>Ac2</i>
NARC-2002 V ₇ **	Control	74.67±1.590	10.33±0.19	1±0.33
	VAM	110.33±11.5	19.33±9.24	4.67±1.53
	Rhz	91.33±1.07	15.67±0.84	7±0.66
	VAM+Rhz	119.33±17.7	13±4.36	5.32±3.79
	RP ₁	94±1.76	9.76±2.36	9.76±2.36
	MRP ₁	98.67±4.35	14±1.20	5.33±1.36
	MRP ₂	106.76±2.52	18±0.88	2±0.33
NARC-2008-3 V ₈ *	Control	68±2.41	7.33±0.68	3±0.00
	VAM	96.87±5.86	11.33±3.51	3.67±0.58
	Rhz	81±0.33	11±0.88	3.67±0.77
	VAM+Rhz	107.67±15.7	10±2.65	4±1.73
	RP ₁	77.67±0.84	8±1.73	3.67±0.51
	MRP ₁	95±2.89	11.67±0.96	4.67±1.35
	MRP ₂	106.67±2.55	16.33±0.77	2.67±0.69
NA RC-2008-4 *** V ₉	Control	61.67±0.96	5.33±0.19	1.33±0.19
	VAM	110.33±11.5	21.67±8.02	5.33±2.52
	Rhz	120.67±2.69	15.67±0.84	13±1.76
	VAM+Rhz	138±5.61	24±1.20	13±1.76
	RP ₁	133.00±1.53	20.33±1.26	14.33±0.84
	MRP ₁	136±1.86	23±2.33	13±2.89
	MRP ₂	143±5.57	23±2.33	13±2.89
NARC-2002 V ₁₀ ****	Control	81.67±3.47	5±1.67	2.33±0.51
	VAM	127.33±4.62	22.33±7.51	7.67±2.52
	Rhz	120.67±2.69	15.67±0.84	11.33±2.27
	VAM+Rhz	159.67±0.19	26.67±1.92	13.33±1.92
	RP ₁	141±4.58	21.67±0.51	12±0.67
	MRP ₁	150.67±1.71	24.33±1.71	15±2.89
	MRP ₂	151±0.33	24±1.20	12.67±1.71

All values mean ± SEM of 3 determinations (replicates)

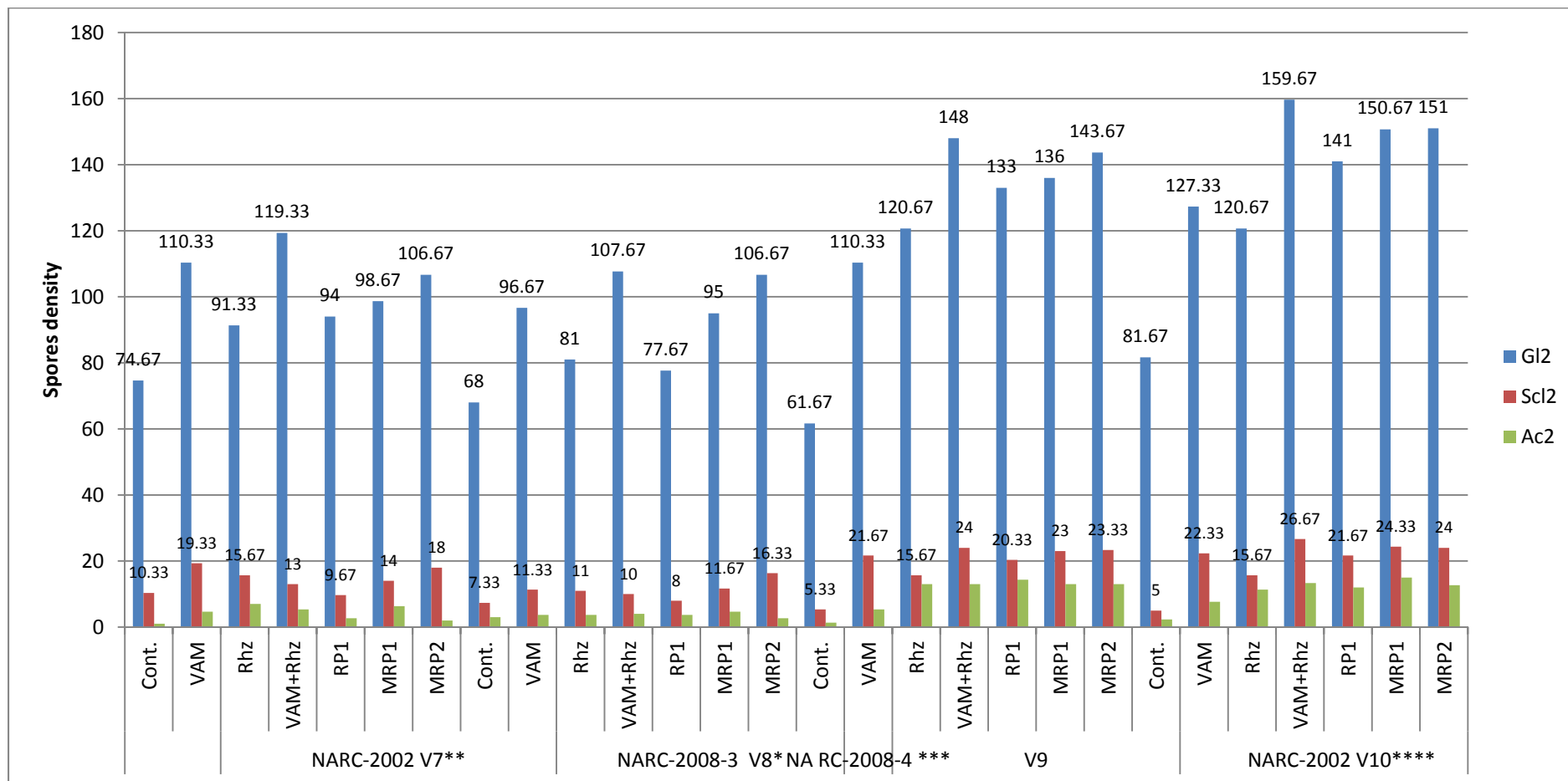


Fig. 31.(Vesicular-) arbuscular mycorrhizal spores density in *Lens culinaris* (V₇-V₁₀) at flowering stage.

Table 32.(Vesicular-) arbuscular mycorrhizal spores density in *Lens culinaris* (V₇-V₁₀) at fruiting stage.

Varieties	Treatments	VAMF spores density		
		<i>Gl3</i>	<i>Scl3</i>	<i>Ac3</i>
NARC-2002 V₇**	Cont.	73.67±0.5	9.67±0.51	2.67±0.19
	VAM	119±6.56	14±6.08	5.67±2.52
	Rhz	95.67±1.3	13±3.28	5.76±0.51
	VAM+Rhz	135.23±7.57	14.13±2.52	6.33±3.06
	RP₁	115.76±4.95	12±0.33	2.33±0.51
	MRP₁	111±4.18	15.60±0.96	5.33±1.02
	MRP₂	112.34±3.60	7.33±1.20	2.34±0.51
NARC-2008-3 V₈*	Cont.	75.31±1.17	6.33±0.19	1.34±0.17
	VAM	106.56±6.11	10.66±2.52	5±2.35
	Rhz	89.67±3.17	9±1.00	5.67±0.49
	VAM+Rhz	126±6.26	12.33±1.53	6.33±3.06
	RP₁	103.67±2.41	10±2.03	3±0.33
	MRP₁	101.67±2.55	9.67±0.19	3±0.67
	MRP₂	112.33±3.06	6.67±0.77	4.33±1.17
NA RC-2008-4 *** V₉	Cont.	68.33±0.96	3.67±0.51	2.67±0.69
	VAM	122.67±2.52	19.67±7.77	6.67±4.04
	Rhz	121±6.69	15±2.19	9.33±1.02
	VAM+Rhz	151±1.86	18.33±1.07	9.33±1.26
	RP₁	143.33±2.78	11±0.88	4±0.88
	MRP₁	150.33±2.78	18.33±1.68	9.33±0.84
	MRP₂	153±2.40	19±2	9.33±0.84
NARC-2002 V₁₀****	Cont.	85±2.89	7.67±1.84	2.67±0.67
	VAM	133.67±10.26	18.33±7.64	7.33±3.21
	Rhz	121±6.69	15±2.19	9.33±1.02
	VAM+Rhz	165.33±4.29	20.67±2.87	10.33±1.39
	RP₁	153.33±2.78	13.67±2.01	6.67±1.50
	MRP₁	163.33±5.09	21±2.89	8.67±0.51
	MRP₂	158.33±2.55	20.67±1.35	11±0.33

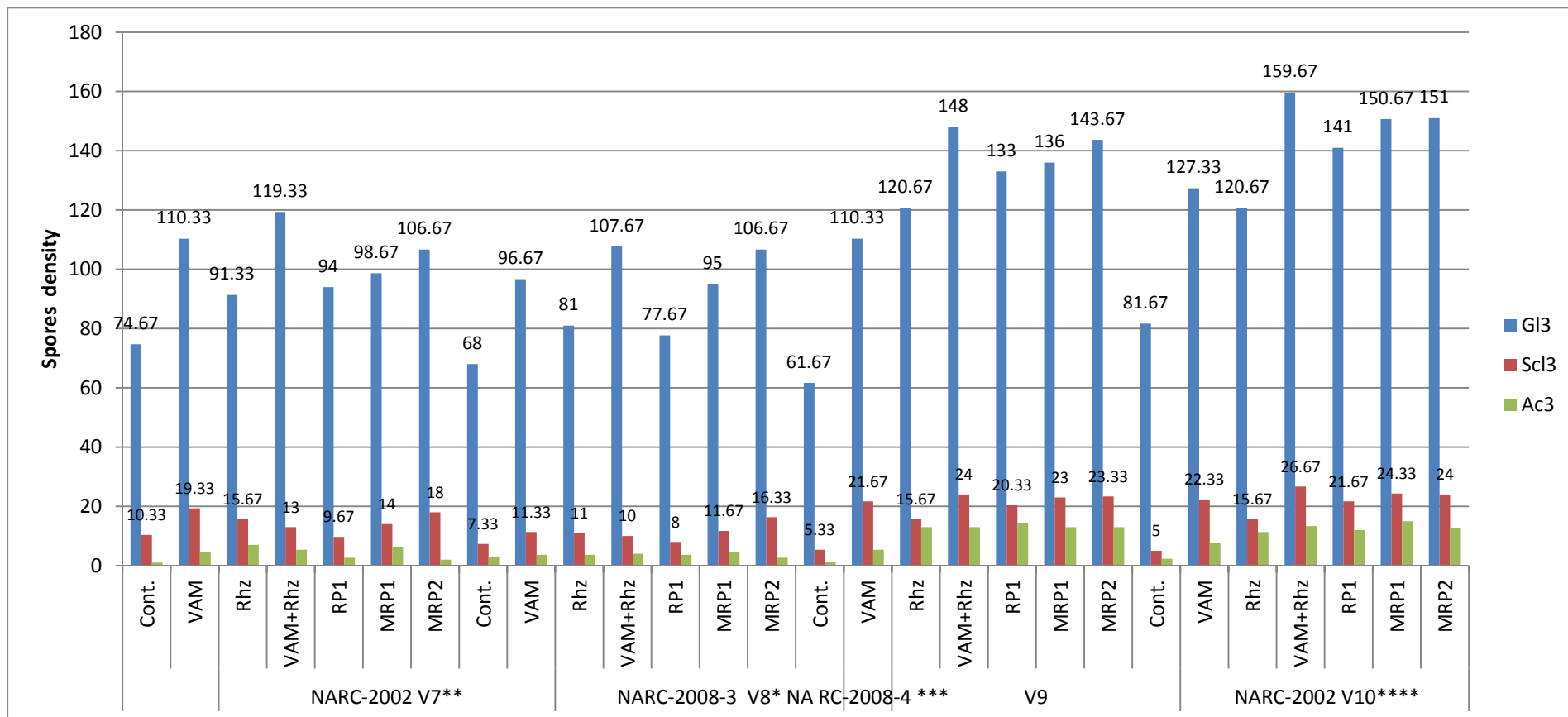


Fig.32. (Vesicular-) arbuscular mycorrhizal spores density in *Lens culinaris* (V₇-V₁₀) at fruitingstage.



Fig. 33. Spores of *Glomus mosseae* (40 x).



Fig. 34. Spore of *Glomus* spp.(10 x).



Fig. 35. Spores of *Sclerocystistaiwanensis* (4x).



Fig. 36. Spores of *Acaulosporamellae* (10x).

B: EXPERIMENTATION

II. Growth Characters

4.1. Effect of AMF-rhizobia and Rockphosphate-AMF on growth

The present experimental work was done with an objective to find out the role of AM, *Rhizobium* and RP alone and combine on growth, productivity and yield response, mineral and proximate composition of mungbean, lentil, pea, burgundy and desmodium varieties of legumes under P deficient soil. To achieve the objective an experiment was designed to find out the response of species and varieties, three of *Vigna radiata* (V₁-V₃), one *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and four of *Lens culinaris* (V₇-V₁₀) to AM, *Rhizobium*, RP inoculation. Growth and yield of all legumes plants inoculated with AM, *Rhizobium* and RP alone and combine were determined at three stages in terms of plant height, number of leaves/plant, number of flowers/plant, number of pods/plant, number of seeds/pod, and length of pod. These parameters were compared with non-inoculated series of plants. In the present research work the following growth parameters were recorded and compared. The effects of different treatment VAM (*Glomus fasciculatum*, *G. mosseae* and *G. aggregatum*, *Sclerocystis* and *Acaulospora* sp), VAM + *Rhizobium*, VAM+RP, *Rhizobium*, rock phosphate (RP), and an uninoculated (control), microbial treatments and fertilizer on the growth parameters, dry matter, yield, proximate and minerals composition of mungbean, lentil, pea, burgundy and desmodium were studied.

Plant height

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on plant height of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀), varieties following seven treatments are given in Tables 43-53. It is evident from results that the treatment of biofertilizer enhanced the plant height compared to the control. The results of ANOVA test regarding the plant height of six cultivars of studied legumes following seven treatments (controlled and uncontrolled) and LSD Table 43 of plant height are shown in ANOVA Tables 33-35. ANOVA showed that varieties, Interaction between varieties and treatments and the effect of treatments were significantly different regarding plant height. The ANOVA

showed that varieties were ($P>0.000$) or (100%) highly significantly different regarding plant height at harvesting stage. Interaction between varieties and treatments was ($P>0.0001$) or (100%) highly significant. The effect of treatment was also 100% highly significant. Our result correlates with the findings of Ashraf *et al.*, 2003; Jia *et al.*, 2004; Bhuiyan, 2004) that both rhizobial and mycorrhizal symbioses can act synergistically on promoting plant growth and fitness. It is evident from our result that VAM inoculation with RP and rhizobium, improved plant growth on both summer and winter cultivars expressed as plant height at three different stages (vegetative, flowering and fruiting) after sowing compared with the uninoculated plants which shown in Fig.53-55. Our results correlate with the finding of Jarande *et al.* (2006) stated that treatments which included rock phosphate (RP) and seed treatment with phosphate solubilizing bacteria (PSB) and *Rhizobium* application RP +PSB+*Rhizobium* recorded higher values of growth as well as yield contributing parameters, plant height, number of branches per plant, number of seeds per plant, and similarly by Omsub (2009) reported that there is a tendency of using these fungi together with rock phosphate to promote plant growth. Our results are also in line with the findings of many workers (Meshram *et al.*, 2000; Niranjana *et al.*, 2002; Sampath & Ganesh, 2003; Gilani&Bharose, 2004; Balachandran *et al.*, 2005; Rajasekaran *et al.*, 2006; Mortimer *et al.*, 2008; Sayeed & Siddiqui, 2007; Patel *et al.*, 2007; Kushwaha, 2007; Khan *et al.*, 2008; Paola & Iulia, 2009; Nishita & Joshi, 2010; Nazir *et al.*, 2011). The lowest plant height was recorded in control treatment it is evident from data in Tables 44-53 and Fig.(45) our findings were in agree with Hani (2009) report that the plant height was significantly higher in VAM inoculated treatment compared to VAM un-inoculated treatment for *Prosopis chilensis* his result was similarly that of Morshed *et al.* (2008) the lowest plant height (44.00 cm) was recorded in control treatment of soyabean. RHZ+VAM and VAM+RP produced the highest plant height which was higher than that of control treatment (control) in all legumes shown in Figs.56-59. This result was in agreement with that of Shivakumar & Sidramappa (2004), where it was reported that plant height of soybean was highest with 20 kg P ha⁻¹. Ramasamy *et al.* (2000) also found that plant height of soybean increased with P at 80 kg ha⁻¹. Khalequzzaman & Hossain (2008) stated that application of *Rhizobium* strains and biofertilizers increased plant growth, yield and yield attributes are, highest number of nodules/plant, the tallest

plant. Data illustrated in the same tables & figures show clearly that the dual inoculation with both symbionts and RP fertilization induced more significant increases in all parameters than inoculation with either *Rhizobium* or VAM alone. Thus, dual infection was the most effective for all cultivars with regard to plant growth. Our result agrees with Chalk *et al.* (2006) observed that dual inoculation with rhizobia and arbuscular mycorrhizal fungi AMF results in a tripartite mutualistic symbiosis and generally increases plant growth to a greater extent than inoculation with only one. Same observation by Mortimer *et al.* (2008) that synergistic effects of the combined application of rhizobia and AM fungi enhance plant growth to a greater extent than singular inoculation. Maximum height was attained at mycorrhizal and rhizobium treatments in combine form in all varieties of legumes shown in Fig.47-48. Our result agrees with the finding of Jia *et al.* (2004) who reported that inoculation with AM fungi promoted biomass production and photosynthetic rates in *Vicia faba* because of the enhanced P supply due to AM fungi inoculation. The plant height was increased as a result of using the biofertilizer and chemical RP fertilizer or the combined treatments of both *Rhizobium* and VAM in the experimental seasons. The plant height was gradually increased with increasing the RP+VAM level and reached its maximum value by applying the full recommended dose using biofertilizer in combine form increased plant height compared to the treatment of each of them alone shown in Tables 44-53 and Fig.50. Our finding matches with Hussain *et al.* (2010) study the influence of phosphorus fertilization and *Rhizobium* inoculation on growth and yield parameters of mungbean (*Vigna radiata*). Our result also in line with Beg & Singh (2009) reported that root nodule dry weight per plant, leaf area index, plant height, dry matter accumulation, branches per plant, pods per plant, seeds per pod, 1000-seed weight, seed yield, enhancement of all parameters as comparative to single inoculation of *Rhizobium* or (PSB) or chemical fertilizer application in green gram (*Vigna radiata*). However, the tripartite cultures in general were significantly effective compared to the other treatments. Similarly Vinicius *et al.* (2009) reported that dual symbiosis formed by AM fungi and *Rhizobium* can be deleterious to *Phaseolus vulgaris* growth depending on the plant variety and the symbionts involved. Others workers reported that inoculation of food legumes (chickpea, green mung, pea, lentil and cowpea etc.) combined inoculation with mycorrhizal, rock

Table 35. ANALYSIS OF VARIANCE

Plant Height at fruiting stage						
K	Degrees of	Sum of	Mean	F		
Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	21.091	5.273	1.6108	0.1717
2	Factor A	6	790.179	131.697	40.2319	0.0000
4	Factor B	9	3199.528	355.503	108.6024	0.0000
6	AB	54	1098.667	20.346	6.2154	0.0000
-7	Error	276	903.469	3.273		

	Total	349	6012.935			

Coefficient of Variation: 5.69%						
LSD value = 2.252 at alpha = 0.050						

Number of Leaves/Plant

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP on number of leaves /plant of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀) varieties following seven treatments are given in Tables 44-53. ANOVA are shown in Tables 36-38. The ANOVA showed that varieties were ($P > 0.000$) or (100%) highly significantly different regarding plant height at harvesting stage. Interaction between varieties and treatments was ($P > 0.0000$) or (100%) highly significant. The effect of treatment was also ($P > 0.0000$) or (100%) highly significant. Our results are in accordance with the Gilani & Bhorsa (2004) who studied the effect of biofertilizers on the growth and yield of green gram (*Vigna radiata*). Different levels of Rockphosphate and bio-fertilizer (*rhizobium* and VAM) were applied resulted in significant number of leaves, plant height, which shown in Fig. 60-61. Our results are according to Balachandran *et al.* (2005) who reported that the effect of seed inoculation with *Rhizobium* and phosphate solubilizing bacteria (*Pseudomonas* and *Bacillus* sp.). Rh + PSB significantly increased plant height, number of branches, number of leaves and leaf area. Different levels of RP chemical fertilizer also led to increase the number of leaves and even branches of plants; however, there were no significant differences between the treatments shown in tables. These results are in agreement with those of Gomaa & Abo-Aly (2001) rock phosphate (RP) is increasingly recognized as potential

Table 38. ANALYSIS OF VARIANCE

Leaves at fruiting stage							
K	Degrees of	Sum of	Mean	F			
Value	Source	Freedom	Squares	Square	Value	Prob	
1	Replication	4	35.360	8.840	7.2736	0.0000	
2	Factor A	6	70.754	11.792	9.7028	0.0000	
4	Factor B	9	18974.403	2108.267	1734.6819	0.0000	
6	AB	54	242.617	4.493	3.6968	0.0000	
-7	Error	276	335.440	1.215			

Total	349	19658.574					

Coefficient of Variation: 9.63%							
LSD value = 1.372 at alpha = 0.050							

Table 39. ANALYSIS OF VARIANCE

Flowers							
K	Degrees of	Sum of	Mean	F			
Value	Source	Freedom	Squares	Square	Value	Prob	
1	Replication	4	37.857	9.464	12.1527	0.0000	
2	Factor A	6	40.617	6.770	8.6925	0.0000	
4	Factor B	9	700.743	77.860	99.9775	0.0000	
6	AB	54	60.697	1.124	1.4433	0.0315	
-7	Error	276	214.943	0.779			

Total	349	1054.857					

Coefficient of Variation: 20.73%							
LSD value = 1.099 at alpha = 0.050							

Number of flowers per plant

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on number of flowers/plant of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀) varieties following seven treatments are given in Tables 44-53 and ANOVA39 and LSD43 are shown respectively. The ANOVA showed that varieties were (P>0.000) or (100%) highly significantly different regarding plant height at harvesting stage. Interaction between varieties and treatments

was ($P > 0.0000$) or (100%) highly significant. The effect of treatment was also ($P > 0.0000$) or (100%) highly significant. The results are in good agreement with that of Naziret *et al.* (2011) who reported that combined inoculation of *Rhizobium* + PSB on black gram variety PU-19, slightly improved growth characters (plant height, dry matter production, number and weight of nodules per plant at maximum flowering) and the yield attributes (branches and pods per plant, seeds per pod, 1000 seed weight), than *rhizobium* and PSB inoculated separately. Khalequzzaman & Hossain (2008) also stated that inoculation of *rhizobium* strains and biofertilizers increased plant growth, number flowers /plant, yield and yield attributes are, highest number of nodules/plant, the tallest plant, highest number of pods/plant, the highest weight of green pods/plant in bush bean as compared to control. The effect of interaction between AM fungi (AMF) and *Rhizobium* in soybean, chickpea and other leguminous plants is also well known (Devi & Reddy, 2000; Athar, 2005; Goss *et al.*, 2002; Antunes *et al.*, 2006; Neveen *et al.*, 2008; Nishita & Joshi, 2010).

Number of pods per plant

Results of VAM, RHZ, RHZ + VAM, RP and VAM+RP inoculation on number of pods/plant of *Vigna radiata* (V_1 - V_3), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V_7 - V_{10}) varieties following seven treatments are given in Tables 44-53 and ANOVA are shown in Table 40. The ANOVA showed that varieties were ($P > 0.000$) or (100%) highly significantly different regarding plant height at harvesting stage. Interaction between varieties and treatments was ($P > 0.0000$) or (100%) highly significant. The effect of treatment was also ($P > 0.0003$) significant. Our results are in good agreement with that of Sayeed & Siddiqui (2007) who reported that combined inoculation of *G. intraradices* with *P. straita* plus *Rhizobium* to pathogen inoculated plants caused greater increase in plant growth, number of pods than by inoculation of *G. intraradices* plus *Rhizobium* or *G. intraradices* plus *P. straita* alone. All legumes cultivars significantly differed in number of pods and seeds/plant, length of pods and seeds/plant, pods/plant shown in Table 40 and Fig. 46, 59. Vinicius *et al.* (2009) have the same findings that dual symbiosis formed by AM fungi and *Rhizobium* can be deleterious to *Phaseolus vulgaris* growth depending on the plant variety and the symbionts involved. Result also

match with Bhuiyan *et al.* (2008) who reported that similar response of the mungbean varieties may be attributed to their parental similarities and similarities in genotypic make-up. The varietal and treatments, *rhizobium*+VAM, VAM+ RP inoculation effects were highly significant ($P>0.0000$) or (100%) Table 40 and Fig. 46, 59. Our result supported by Gilani *et al.* (2004) who studied the effect of biofertilizers on the yield of green gram (*Vigna radiata*). Different levels of MRP and bio-fertilizer were applied resulted in significant number of seeds per pod, number of pods per plant shown in Fig. 52-54. Same finding by Jalaluddin (2005) that combined inoculation of VAM fungus, *Glomus macrocarpum* and *Bradyrhizobium japonicum* in soybean variety William 82 promoted maximum growth and yield. Dual inoculation with *Rhizobium* and VAM or RP either as seed or as soil inoculation significantly increased the seed yield agree with the statement of Muhammad *et al.* (2004) reported that effect of phosphorus and *Rhizobium* inoculum on the yield and yield components of mungbean cv. NM- 92. Similarly, Vishram *et al.* (2007) reported three biofertilizers viz., PSB, *Rhizobium* and VAM were tested against number of pods/plant. Our Result showed that VAM produced significantly better growth attributes when combine with RP or Rhz. yield attributes and yield over rest of the biofertilizers and fertilizer (RP) alone. VAM gave more dry matter, higher seeds per plant than *Rhizobium*, and RP respectively. Our result in line with Khan *et al.* (2005) reported the effect of seed inoculation with *Rhizobium* along with various levels of phosphorus on chickpea (cv. Karak-1) growth the results revealed significant increase in pod per plant, seed weight and yield. The highest number of pods per plant was found in VAM +RHZ shown in Fig. 51, 55. Treatments which was statistically superior to the rest of the treatments. The lowest number of pods per plant was observed in the control plants. The results of the experiment were in accordance with those of Ramasamy *et al.* (2000) where it was reported that P at 80 kg ha⁻¹ produced significantly higher number of pods per plant of soybean. Shivakumar & Sidramappa (2004) also found that the highest number of pods per plant of soybean with 40 kg P ha⁻¹. *Rhizobium* inoculation in mungbean increases number of pods and seed yield (Ashraf *et al.*, 2003; Bhuiyan, 2004; Yadav *et al.*, 2007; Bhuiyan *et al.*, 2008). Different levels of rock phosphate with VAM inoculation influenced the number of pods per plant result agree with Sundara *et al.* (2004) noticed that the application of 80 kg P₂O₅/ha resulted in the

highest number of seeds per pod (5.74) of pea. Similar results were obtained by Naher (2000) who reported that *rhizobium* inoculation did not significantly increase the number of mature seeds/pod. El-Habbasha *et al.* (2005) noticed that increasing P levels increased number of seeds per plant of groundnut. Zafar *et al.* (2003) also found that the application of 75 kg P₂O₅/ha gave the highest number of seeds per plant (1.89) of lentil. Earlier workers have reported variable responses of growth, productivity & yield, nodulation, nitrogen fixation & nutrient uptake to rhizobial & mycorrhizal alone or in combined inoculation in different leguminous crops, Pea (Geneva *et al.*, 2006; Mishra & Geeta, 2010; Joyce *et al.*, 2010).

Table 40. ANALYSIS OF VARIANCE

Number of Pod/plant						
K	Degrees of	Sum of	Mean	F		
Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	13.474	3.369	4.1781	0.0027
2	Factor A	6	89.097	14.850	18.4180	0.0000
4	Factor B	9	882.846	98.094	121.6665	0.0000
6	AB	54	84.674	1.568	1.9449	0.0003
-7	Error	276	222.526	0.806		

Total	349	1292.617				

Coefficient of Variation: 22.81%						
LSD value = 1.118 at alpha = 0.050						

Number of seeds per pod

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on number of pods/plant of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀) varieties following seven treatments are given in Tables 44-54 and ANOVA are shown in Table 41. ANOVA showed that varieties were (P>0.000) or (100%) highly significantly different regarding plant height at harvesting stage. Interaction between varieties and treatments was (P>0.0000) or (100%) highly significant. The effect of treatment was also (P>0.0002) or (98%) significant. With the increase of MRP fertilizers levels increased the number of seeds per pod. The

highest number of seeds per pod was found in MRP₂ treatment which was higher than that of control plants shown in Figs.53-54. ANOVA are shown in Table 41, treatment *rhizobium* and VAMinoculation combine and alone significantly increased number of seeds/pod result agree with the Jagvir *et al.* (2004) that dual inoculation, *rhizobium* and VAM resulted in increase in grain yield respectively, over no inoculation in green gram. The effect of variety and inoculation on seeds/pod was significant and their interaction effect was also significant Table 41 and Fig. 47-48, 51. The number of seeds/pod differed significantly among the varieties Tables 44-54. Our result match with Chatterjee & Bhattacharjee (2002) reported that the percentage increase in grain yield over control was observed to be significantly higher in plants inoculated with *Rhizobium* strains and phosphate solubilizing bacteria. similar result were found by Kumar & Chandra (2008) and Vijla & Jebaraj (2008) who observed slight improvement in seed yield due to combined inoculation of *rhizobium* + PSB. Green mungbean produced the highest number of seeds/pod, which was statistically similar to all other varieties shown in Tables 44-53. *Rhizobium* and VAMinoculation, rock phosphate application significantly increased number of seeds/pod Table 41 and Fig. 49-50. Similar results were obtained by Jarande *et al.* (2006) who stated that treatments which included rock phosphate (RP) and seed treatment with phosphate solubilizing bacteria (PSB) and *Rhizobium* application of RP and +PSB+*Rhizobium* recorded higher values of growth as well as yield contributing parameters, plant height, number of branches per plant, dry matter per plant, seed yield per plant, number of seeds per plant. Variety x *rhizobium* interaction effect on the number of seeds/pod was statistically significant ANOVA Table 41. Zaidi & Khan (2006) reported that green gram seed yield increased even further, by 15% - 17%, by inoculation with *Bradyrhizobium* + *G. fasciculatum* and *G. fasciculatum* + *B. subtilis*. Higher number of seeds/pod was observed in inoculated plants. The symbiotic potential of AM fungus, *G. intraradices* alone and/or in combination with rhizobial strains in legumes cultivars Tables 44-53. Our result supported by Meghvansi & Mahna (2009), who found that dual inoculation of *rhizobium* + VAM was superior over single inoculation of VAM, *rhizobium* in all cultivars and produced higher seeds of plants cultivars respectively when compared to control are supported by Muhammad *et al.* (2006) who stated that seed yield per plant was significantly affected by *Rhizobium* inoculation and fertilizer

applications. Others workers have been reported that VAM-fungi and *Rhizobia* to increase the growth and yield of some legumes (Gupta, 2004; Shivakumar *et al.*, 2004; Zaidiet *al.*, 2004; Satyawati *et al.*, 2005; Bhat *et al.*, 2005; Jat & Ahlawat, 2006; Badr *et al.*, 2006; Goud & Reddy, 2007; Singh, 2008; Yadegari *et al.*, 2008). But RP also in combination with VAM increase the growth and yield of studied legumes our result match with Fatima *et al.* (2006) who found that the effect of growth was highly significant (α 0.05) with an increase in root/shoot dry and fresh weight in plants with mixture of VAM/*Rhizobium* inoculums with Rock phosphate on soybean.

Table 41. ANALYSIS OF VARIANCE

		Number of Seed/pod				
K	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	20.474	5.119	3.8990	0.0043
2	Factor A	6	96.840	16.140	12.2946	0.0000
4	Factor B	9	7278.789	808.754	616.0650	0.0000
6	AB	54	139.331	2.580	1.9655	0.0002
-7	Error	276	362.326	1.313		
Total		349	7897.760			
Coefficient of Variation: 18.84%						
LSD value = 1.427 at alpha = 0.050						

Pod length

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on number of pods/plant of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀) varieties following seven treatments are given in Tables 44-53 and ANOVA are shown in Table 42. The ANOVA showed that varieties were ($P > 0.000$) or (100%) highly significantly different regarding plant height at harvesting stage. Interaction between varieties and treatments was ($P > 0.0000$) or (100%) highly significant. The effect of treatment was also ($P > 0.0000$) or (100%) highly significant. Our results agree with Jagviret *al.* (2004) who reported that dual inoculation, *Rhizobium* and VAM resulted in increase in grain yield respectively, over no inoculation, the yield of green gram, attributed to cumulative effect of growth attributes viz., plant

height, number of branches per plant, number of trifoliate leaves, leaf area index, dry matter accumulation per plant, crop growth rate and net assimilation rate and yield attributes viz., pods per plant, pod length, seeds per pod, 1000-seed weight and seed yield per plant. Other workers finding agree our results (Niranjan *et al.*, 2002; Kalipada & Singh, 2003; Potdukhe & Guldekar, 2003; Jain & Pushpendra, 2003; Baba *et al.*, 2006).

Table 42. **ANALYSIS OF VARIANCE**

Pod Length						
K	Degrees of	Sum of	Mean	F		
Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	2.364	0.591	1.9997	0.0948
2	Factor A	6	69.837	11.639	39.3747	0.0000
4	Factor B	9	4333.307	481.479	1628.7790	0.0000
6	AB	54	78.354	1.451	4.9085	0.0000
-7	Error	276	81.588	0.296		
Total	349	4565.449				

Coefficient of Variation: 11.18%

Table 43. LSD values of treatments, varieties and interaction on the yield angrowth parameters of all legumes.

Growth parameters	Treatment LSD	Varietal LSD	Interaction LSD
PH ₁ (cm)	0.7817	0.9343	2.472
PH ₂ (cm)	2.389	2.855	7.554
PH ₃ (cm)	0.5936	0.8514	2.252
LV ₁	0.4711	0.5631	1.490
LV ₂	0.5368	0.6416	1.698
LV ₃	0.4340	0.5187	1.372
FL ₂	0.3475	0.4153	1.099
No. of Pod/pl	0.4225	0.4225	1.118
No. of Seed/pod	0.4511	0.5392	1.118
Pod length(cm)	0.4225	0.2560	0.6774

LSD value at alpha = 0.050

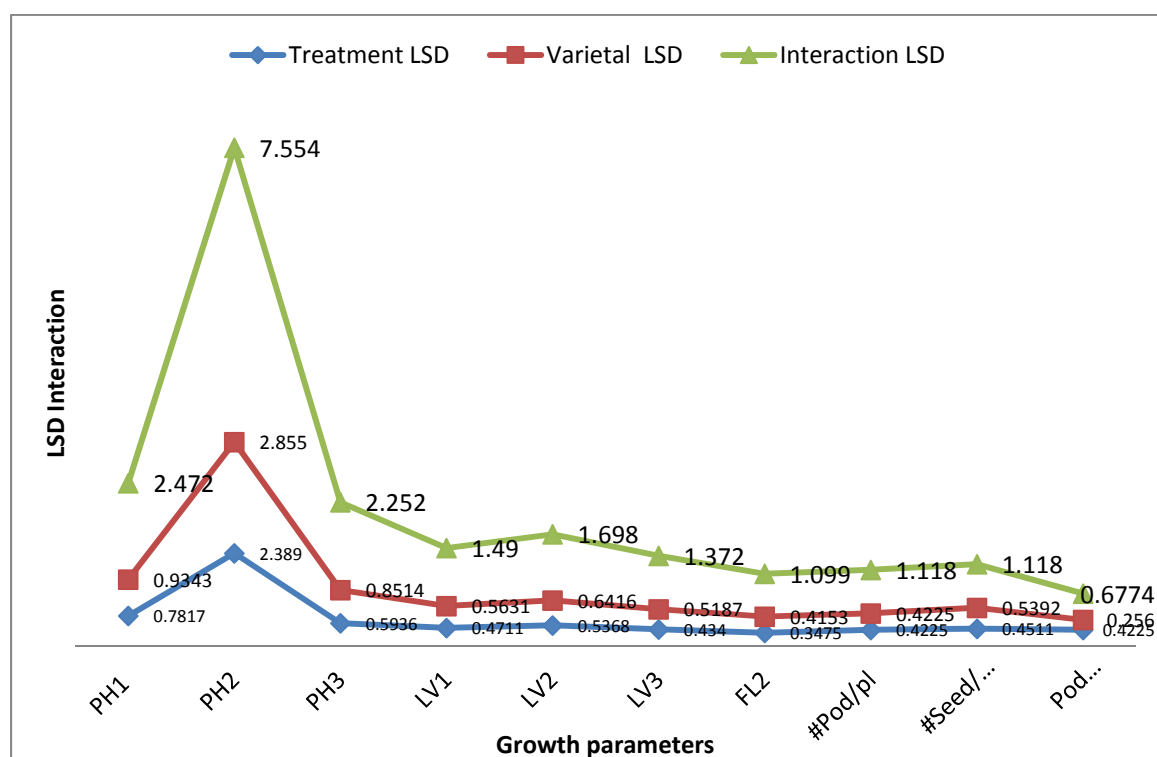


Fig. 37. The LSD interaction, treatment and varietal effects of different varieties of studied legumes and VAM fungi, *rhizobium* and rockphosphate.

Table 44. Influence of VAM, *Rhizobium* and RP on growth and yield on *Vigna radiata* NIAB-92 (V₁).

Treatment	Vegetative stage			Flowering stage				Fruiting stage		
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	flow/pl	Plant height (cm)	Number of leaves	Pods/plant	Pod length cm plant ⁻¹	seeds plant ⁻¹
Control	11.38±0.15	4.2±0.09	29.52±0.13	3.6±0.1	1.6±0.23	0.1±3.01	3.2±2.84	1.6±0.19	8.56±0.07	9.2±0.14
VAM	17.9±0.25	4.4±0.11	32.76±0.18	3.2±0.09	2.4±0.11	3.16±0.13	3.6±0.11	2.4±0.11	9.42±0.11	10.6±0.11
RHZ.	14.58±0.10	4.4±0.11	28.9±0.26	3.4±0.11	2.2±0.17	1.04±0.33	3±0.60	1.6±0.11	8.44±0.2	9.4±0.23
VAM+ Rhz.	18.19±0.24	4±0.14	31.6±0.11	3.8±0.14	3±0.06	7.66±0.24	17.7±0.09	2.8±0.09	10.26±0.21	10.6±0.18
RP₁ 15gm	15±0.10	4±0.19	24.4±0.19	3.8±0.09	2.8±0.09	7.9±3.20	18.4±3.10	2.2±0.21	7.62±0.06	9.4±0.21
MRP₁ 30 gm	16.1±0.12	4.2±0.17	25.42±0.08	3.6±0.11	2.8±0.17	5.78±0.18	3.2±0.17	3±0.1	7.88±0.08	9.8±0.17
MRP₂ 60gm	16.23±0.16	3.50±0.2	26.78±0.21	3.8±0.09	3.25±0.14	6.40±0.21	3.75±0.23	3.5±0.22	7.90±0.08	9.50±0.18

All values mean ± SEM of 5 determinations (replicates)

Table 45.Influence of VAM, *Rhizobium* and RP on growth and yield on *Vigna radiata* NIAB-98 (V₂).

Treatment	Vegetative stage			Flowering stage				Fruiting stage		
Biofertilizers	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers/ plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	14.5±0.23	3.8±0.09	31.32±0.12	3.8±0.09	2±0.14	34.5±0.11	3.8±0.09	1.8±0.22	8.78±0.06	10±0.14
VAM	19.6±0.21	4.6±0.11	34.64±0.13	4.4±0.11	2.4±0.11	36.24±0.16	4±0.14	2.2±0.09	10.14±0.12	11.4±0.11
RHZ.	16.9±0.29	3.8±0.17	29.8±0.10	3.6±0.18	2±0.14	33.14±0.23	3.2±0.22	1.6±0.11	8.64±0.21	10.2±0.26
VAM+Rhz.	19.4±0.16	3.4±0.11	30.24±0.92	3±0.14	2.6±0.18	35.86±0.39	2.8±0.17	2.2±0.09	11.22±0.16	11.6±0.11
RP₁ 15gm	13.82±0.11	3.6±0.18	21±0.17	3.4±0.11	2.4±0.11	28.28±0.18	3±0.14	2±0.14	8.08±0.14	9.2±0.17
MRP₁30gm	13.58±1.33	9.6±2.38	23.32±2.29	3.6±0.18	8.18±2.43	24.36±2.44	3.2±0.26	3.44±0.54	9.4±0.12	13.58±1.33
MRP₂60gm	21.2±0.20	4±0.14	25.78±0.07	4±0.14	2.8±0.09	35.66±0.25	4±0.14	2.6±0.11	10.24±0.20	9.6±0.23

All values mean ± SEM of 5 determinations (replicates)

Table 46. Influence of VAM, *Rhizobium* and RP on growth and yield on *Vigna radiata* NIAB-2006 (V₃).

Treat.	Vegetative stage			Flowering stage				Fruiting stage		
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers/ plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	16.98±0.28	5.6±0.1	30.86±0.18	5.2±0.17	2.4±0.23	33.56±0.14	5.2±0.17	2±0.20	8.98±0.04	10.6±0.18
VAM	20.4±0.30	5.8±0.09	35.64±0.20	5.8±0.09	3.4±0.11	36.44±0.14	5.8±0.09	2.2±0.17	11.14±0.15	12±0.14
RHZ.	21.72±0.27	4.4±0.23	35.14±0.64	4.4±0.023	3.2±0.22	36.4±0.40	4.6±0.23	2.6±0.23	9.64±0.17	9.8±0.17
VAM+Rhz.	24.2±0.23	5±0.30	32.72±0.53	5±0.30	2.8±0.16	36.4±0.36	5.2±0.23	3.2±0.12	11.96±0.24	11.6±0.10
RP₁15gm	15.02±0.35	4.8±0.17	25±0.82	4.8±0.17	3±0.20	30.08±0.18	5±0.14	2.6±0.11	10.96±0.15	10.8±0.17
MRP₁ 30gm	21.2±0.20	4.4±0.23	27.78±0.16	4.8±0.17	3±0.14	37.2±0.23	4.8±0.17	2.6±0.11	11.46±0.17	11±0.14
MRP₂60gm	22±0.97	4.8±0.17	28.18±0.30	4.8±0.17	3.6±0.11	38.34±0.25	4.8±0.09	3.6±0.11	12.16±0.08	11.6±0.11

All values mean ± SEM of 5 determinations (replicates)

Table 47. Influence of VAM, *Rhizobium* and RP on growth and yield of *Macroptilum bracteatum*.

Treatment	Vegetative stage			Flowering stage				Fruiting stage		
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers/ plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	13.7±0.40	6.4±0.33	3.38±0.68	2.28±0.4	1.30±0.26	1.41±0.28	0.89±0.18	0.84±0.17	0.75±0.15	1.14±0.23
VAM	19.4±0.16	7.8±0.26	30.2±0.92	6±0.37	3±0.14	35.8±0.39	2.8±0.17	2.8±0.17	5.5±0.10	13.8±0.17
RHZ.	17.9±0.36	5.20±0.26	35.58±0.34	3.20±0.09	3.20±0.17	33.98±0.17	4.20±0.17	2.40±0.23	5.12±0.18	12.2±0.26
VAM+Rhiz.	22.30±0.3	6.20±0.36	37.82±0.15	5±0.28	3.80±0.33	38.44±0.16	4.80±0.17	3.80±0.09	6.24±0.10	16±0.20
RP₁15gm	15.1±0.26	4.8±0.17	27.98±1.45	3.2±0.09	3.2±0.17	33.98±0.22	4.2±0.17	2.4±0.23	5.24±0.25	14.4±0.33
RP₁30gm	19.7±0.08	5.2±0.26	36.38±0.39	3.2±0.09	3.2±0.17	38.38±0.20	4.2±0.17	2.4±0.23	5.6±0.11	14.8±0.38
MRP260gm	21.5±0.27	5.2±0.26	37.9±0.34	3.2±0.09	3.2±0.17	39.18±0.19	4.2±0.17	2.4±0.23	6.4±0.12	16.4±0.4

All values mean ± SEM of 5 determinations (replicates)

Table 48. Influence of VAM, *Rhizobium* and RP on growth and yield of *Pisum sativum*.

Treatment	Vegetative stage			Flowering stage				Fruiting stage		
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers /plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	9.78±0.28	15.6±0.33	29.48±0.34	18±0.28	4.6±0.23	31.56±0.34	18.2±0.22	3±0.20	5.4±0.15	3.2±0.17
VAM	11.28±0.34	16.4±0.52	33.8±0.27	19.8±0.30	4.4±0.23	34.6±0.11	21.2±0.46	3.4±0.18	5.9±0.08	7±0.14
RHZ.	12.26±0.45	18.8±0.46	27.9±0.16	10.6±0.48	5.4±0.11	35.22±0.19	19.6±0.18	4.2±0.09	5.94±0.05	5.8±0.17
VAM+Rhiz.	13.22±0.28	18.6±0.48	32.96±0.47	15.2±0.92	5±0.14	35.66±0.19	22.6±0.74	4.2±0.17	6.76±0.06	7.8±0.17
RP₁15gm	10.86±0.37	17±0.37	25.7±0.39	8.8±0.36	4.6±0.11	30.02±0.16	19±0.42	2.6±0.48	5.78±0.21	5.2±0.17
MRP₁ 30gm	11.74±0.50	17.8±0.38	28.5±0.41	9.8±0.17	4.8±0.17	31.22±0.23	19.8±0.26	4±0.14	5.78±0.21	6.4±0.23
MRP₂60gm	13.26±0.66	19.6±0.18	27.7±0.59	10.6±0.18	5.4±0.11	32.42±0.29	21±0.24	5±0.20	5.78±0.21	6.2±0.73

All values mean ± SEM of 5 determinations (replicates)

Table 49. Influence of VAM, *Rhizobium* and RP on growth and yield of *Desmodium adscendens*.

Treatment	Vegetative stage		Flowering stage					Fruiting stage		
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers /plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	10.44±0.12	5.4±0.33	22.7±0.80	5.8±0.46	3.2±0.26	29.1±0.37	5±0.20	2.4±0.18	1.4±0.07	1.6±0.11
VAM	16.7±0.40	4.6±0.23	29.38±0.18	4.8±0.33	4.4±0.23	30.48±0.21	5.2±0.30	2.8±0.38	2.28±0.03	3±0.20
RHZ	14.5±0.21	3.8±0.17	26.98±0.50	3.8±0.09	3.8±0.09	25.48±1.72	5.2±0.30	2.8±0.17	2±0.04	2.8±0.17
RHZ+VAM	15.64±0.64	5.2±0.26	27.02±0.41	4±0.14	3.8±0.33	31.86±0.43	3.8±0.09	3.2±0.17	2.46±0.01	3.8±0.09
RP₁15gm	14.16±0.20	3.2±0.17	25.74±0.36	3.8±0.22	3.6±0.23	28.7±0.14	4.6±0.27	3±0.20	1.75±0.05	2.6±0.11
MRP₁ 30gm	15.16±0.12	3.8±0.26	27.58±0.35	4.6±0.18	4±0.14	29.98±0.32	4.8±0.26	3.6±0.23	2±0.05	3.2±0.17
MRP₂60gm	15.56±0.19	4.4±0.27	27.58±0.35	4.2±0.22	4±0.14	30.0±0.24	4.6±0.27	4.4±0.41	2.34±0.03	3.4±0.11

All values mean ± SEM of 5 determinations (replicates)

Table 50.Influence of VAM, *Rhizobium* and RP on growth and yield of *Lens culinaris* NARC 2008-2 (V₇).

Treatment	Vegetative stage		Fruiting stage			Flowering stage				
Biofertilizers	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers/ plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	3.58±2.64	13±1	23.08±0.75	14.4±1.82	4.6±1.14	24.46±0.58	15.6±1.34	3.4±1.14	1.2±0.16	1.4±0.89
VAM	4.38±0.37	14.8±0.17	26.32±0.24	15.6±0.23	5.4±0.23	28.64±0.16	18±0.32	5.8±0.17	1.64±0.03	1.8±0.09
RHZ.	6.18±0.27	14.3±0.09	23.92±0.16	15.2±0.33	4.8±0.22	26.3±0.17	16.4±0.30	4.2±0.17	1.4±0.04	1.6±0.11
VAM+RHZ	5.08±0.55	18.6±0.30	27.72±0.24	18.2±0.17	6.6±0.11	29.6±0.13	18.6±0.33	6.6±0.11	1.78±0.04	2±0.00
RP₁15g	7.88±0.16	15.6±0.23	26.16±0.21	16.2±0.17	5.4±0.30	28.1±0.28	18.4±0.23	5±0.20	1.52±0.20	1±0.14
MRP₁30g	9.36±0.10	16.4±0.23	54.36±7.29	17±0.20	6±0.14	29.24±0.10	19.2±0.17	5.4±0.18	1.6±0.02	1.4±0.11
MRP₂ 60g	0.16±0.08	17.6±0.30	43.04±5.91	17.8±0.30	6.2±0.09	29.24±0.10	19.2±0.17	5.4±0.18	1.72±0.03	1.6±0.11

All values mean ± SEM of 5 determinations (replicates)

Table 51. Influence of VAM, *Rhizobium* and RP on growth and yield of *Lens culinaris* NARC 2008-3(V₈).

Treatment	Vegetative stage		Fruiting stage			Flowering stage				
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flower s/plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	12.2±0.26	10.4±0.41	18.1±0.31	13.2±0.17	3.6±0.23	20.42±0.15	15.2±0.26	2.6±0.18	1±0.01	1±0.14
VAM	18.6±0.30	13.8±0.26	23.98±0.21	14.2±0.17	4.4±0.11	26.7±0.32	16.6±0.52	5±0.00	1.3±0.04	1.4±0.11
RHZ.	12.72±0.40	12.8±0.17	21.52±0.16	12.8±0.26	4±0.20	24.5±0.30	13.6±0.11	3.6±0.11	1.18±0.03	1.4±0.11
VAM+RHZ	20.88±0.10	18.6±0.30	27.3±0.34	18±0.20	6.6±0.11	29.6±0.13	18.6±0.33	6.6±0.11	1.78±0.04	2±0.00
RP₁15gm	15.12±0.12	14.2±0.17	24.36±0.21	13.6±0.23	4.2±0.17	25.3±0.45	15.8±0.38	4±0.24	1.36±0.04	1.4±0.11
MRP₁30g	19.36±0.10	15.2±0.17	25.36±0.18	15.2±0.22	4.8±0.30	29.24±0.10	19.2±0.17	4±0.14	1.34±0.02	1.8±0.09
MRP₂60g	20.16±0.09	17.2±0.36	25.64±0.17	17±0.24	4.6±0.18	27.36±0.29	19.6±0.11	5±0.00	1.62±0.03	2±0.00

All values mean ± SEM of 5 determinations replicates)

Table 52. Influence of VAM, *Rhizobium* and RP on growth and yield of *Lens culinaris* NARC 2008-4 (V₉).

Treatment	Vegetative stage		Fruiting stage			Flowering stage				
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No. flower s/plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	19.2±0.17	16.8±0.17	27.6±0.34	17±0.20	1.22±0.24	29.08±0.24	18.8±0.09	6.2±0.17	1.44±0.05	1.6±0.18
VAM	26.8±0.38	16.8±0.17	30.86±0.16	17.4±0.46	6.8±0.26	32.12±0.24	19.4±0.18	6.6±0.27	1.8±0.03	2±0.00
RHZ.	22.4±0.86	18.8±0.22	25.84±0.59	17.2±0.48	5.4±0.30	30.96±0.13	19.4±0.18	5.8±0.26	1.68±0.03	1.8±0.09
VAM+RHZ	27.08±0.48	18.8±0.33	29.12±0.33	19.2±0.17	7.2±0.09	32.26±0.32	19.6±0.11	7.2±0.11	1.88±0.01	2±0.00
RP₁15g	25.64±0.76	15.6±0.23	26.16±0.21	16.2±0.17	5.4±0.30	27.9±0.25	18.4±0.23	5±0.20	1.52±0.02	1±0.14
MRP₁30g	29.94±1.12	17.4±0.23	27.12±0.42	18.4±0.23	5.6±0.23	30.44±0.19	19.2±0.17	5.4±0.18	1.66±0.02	1.4±0.11
MRP₂ 60g	23.76±0.95	18.8±0.17	29.2±0.34	19±0.20	6.2±0.09	31.24±0.46	19.6±0.11	6±0.14	1.84±0.02	1.6±0.11

All values mean ± SEM of 5 determinations (replicates)

Table 53.Influence of VAM, *Rhizobium* and RP on growth and yield of *Lens culinaris* NARC – 2002(V₁₀).

Treatment	Vegetative stage		Fruiting stage			Flowering stage				
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	No.flowers /plant	Plant height (cm)	Number of leaves	Pod/plant	Pod length(cm)	seeds/pod
Control	21.4±0.33	18.6±0.23	31.94±0.43	17±0.20	6.8±0.17	33.24±0.52	19.2±0.17	7±0.14	1.48±0.07	1.4±0.11
VAM	32.06±0.36	19±0.14	35.34±0.30	18.6±0.23	7.4±0.27	35.52±0.58	19.8±0.09	7.6±0.11	1.84±0.01	2±0.00
RHZ.	31.48±0.24	18.8±0.22	31.24±0.46	18.6±0.23	6.2±0.26	33.16±0.52	19.2±0.17	6.4±0.11	1.78±0.03	1.6±0.11
VAM+Rhiz	34.48±0.55	19.8±0.09	29.12±0.33	19.2±0.17	7.2±0.09	32.26±0.32	19.6±0.11	7.4±0.11	1.88±0.01	2±0.00
RP₁15g	31.8±0.29	19.2±0.09	32.44±0.36	18.6±0.23	6.2±0.26	33.16±0.52	19.4±0.11	6.8±0.17	1.84±0.02	1.6±0.11
MRP₁30g	32.04±0.27	17.4±0.23	33.52±0.29	18.4±1.14	5.6±0.23	36.44±0.25	19.8±0.09	6.4±0.11	1.7±0.02	1.6±0.11
MRP₂60g	23.76±0.95	18.8±0.17	33.98±0.46	19.6±0.18	6.2±0.09	31.24±0.46	19.6±0.11	7.6±0.11	1.88±0.01	2±0.00

All values mean ± SEM of 5 determinations (replicates)

Table 54. Effect of biofertilization treatment, RP treatments and their combination on the growth parameters of legumes.

Parameters	Treatments(A)	Varieties(B)	AxB	CV
PH1	283.906	910.579	21.756	10.60%
PH2	220.787	301.730	106.619	20.62%
PH3	131.697	355.503	20.346	5.69%
LV1	21.259	1436.833	26.735	10.95%
LV2	29.379	1465.505	14.732	13.43%
LV3	11.792	2108.267	4.493	9.63%
FL2	6.770	77.860	1.124	20.73%
No.of Pod/plant	14.850	98.094	1.568	22.81%
Pod length	11.639	481.479	1.451	11.18%
No.of Seed/pod	16.140	808.754	2.580	18.84%

Means square (5 replicates)

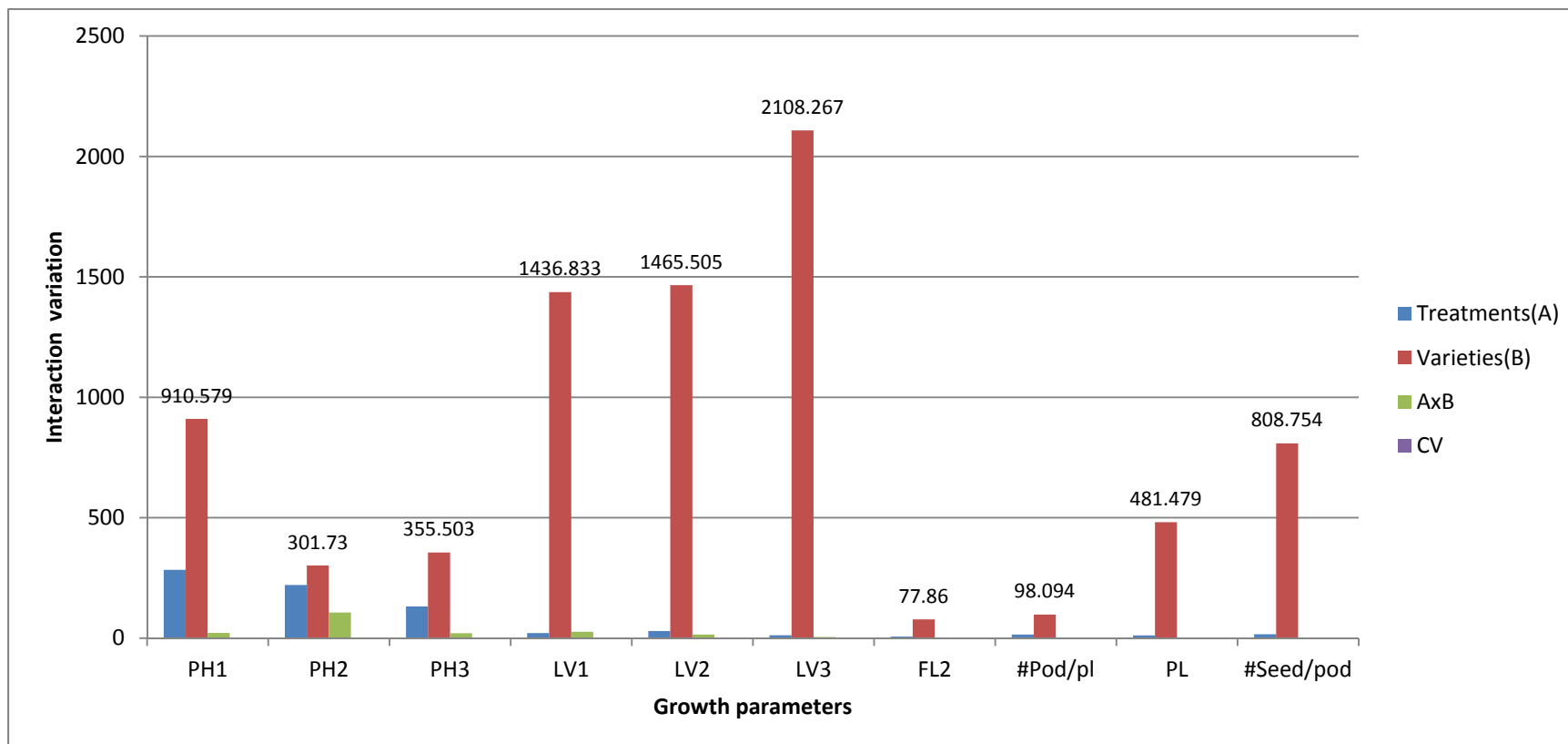


Fig.38. Effect of biofertilization treatment, RP treatments and their combination on the growth parameters of legumes.



Fig. 39. Pot experiment of *Macropitulum bracteatum*(V₄).



Fig. 40. Pot experiment of *Lens culinaris*.



Fig. 41. Pot experiment of *Lens culinaris* at harvesting/pod stage.



Fig. 42. VAM show varietal growth response in *Vigna radiata* L. NAIB-98 and NAIB-2006.



Fig. 43. Effect of Rockphosphate inoculation on plant height of *Vigna radiata* L. NAIB-92.



Fig. 44. Effect of VAM+RHZ. inoculation on pods of *Vigna radiata* L. NAIB-92, NAIB-98 and NAIB-2006.



Fig.. 45. Effect of VAM ,VAM+RHZ. & VAM+MRP inoculation on pods of *Vigna radiata* NAIB-2006.



Fig. 46. Effect of VAM ,VAM+RHZ. & VAM+MRP inoculation on pods of *Vigna radiata* L. NAIB-98.



Fig. 47. Effect of VAM +RP inoculation on plant height of *Vigna radiata* L. NAIB-92, NAIB-98 and NAIB-2006.



Fig. .48. Effect of VAM +RHZ. inoculation on plant height of *Vigna radiata* L. NAIB-92, NAIB-98 and NAIB-2006.



Fig. 49. Effect of VAM +RHZ. inoculation on pods/plant of *Vigna radiata* L. NAIB-92, NAIB-98 and NAIB-2006.



Fig. 50. Effect of VAM+RP inoculation on pods of *Lens culinaris* NARC 2008-4.



Fig. 51. Effect Effect of VAM+RP inoculation on pods of *Lens culinaris*NARC 2008-4.



Fig. 52. Effect of VAM+RP inoculation on pods of *Lens culinaris*NARC 2008-3.



Fig. 53. Effect of VAM ,RHZ,VAM+RHZ. inoculation on plant height of *Lens culinaris*NARC 2008-2.



Fig. 54. Effect of VAM ,RHZ,VAM+RHZ.,inoculation on plant height of *Lens culinaris*NARC 2002.



Fig. 55. Effect of VAM ,RHZ,VAM+RHZ.,inoculation on plant height of *Lens culinaris*NARC 2008-3.



Fig. 56. Effect of VAM ,RHZ,VAM+RHZ.,inoculation on plant height of *Lens culinaris*NARC 2008-4.



Fig. .57. Effect of AM inoculation on pods of *Lens culinaris* NARC 2002, NARC 2008-2, NARC 2008-3 and NARC 2008-4.



Fig. 58. Effect of VAM inoculation on plant height of *Macroptilum bracteatum*.



Fig. 59. Effect of VAM inoculation on plant height of *Desmodium adscendens*.



Fig. 60. Effect of VAM, VAM+RHZ and VAM+RP inoculation on pods per plant of *Pisum sativum*.

4.4 Effect of Mycorrhizae, rhizobium (Rhiz.) and rock phosphate (RP) inoculation on shoot dry weights

Results of VAM inoculation on dry weight of *Vigna radiata*, *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* are given in Table 55 and Fig. 64. The data pertaining to dry weight values of varieties (V₁ –V₃ and V₇-V₁₀) and species in Table 12a. The results showed that V₃ followed by V₂, V₁, *Pisum sativum*, *Desmodium adscendens*, V₁₀, V₇, V₉, *Macroptilum bracteatum* and V₈, 8.33g, 7.63g, 7.01g, 6.16g, 4.81g, 4.4g, 3.95g, 3.79g, 3.66g and 2.97g respectively and V₃ had more weight and V₈ had less dry weight. There was great variation among all cultivars. Our result strongly supported by Morshed, *et al.* (2008) who reported that average dry weight of root per plant varied insignificantly from 0.96 to 1.25 g due to the treatment variations. And also by the finding of Khan *et al.* (2008) that shoot and root dry weight was significantly increased due to the dual inoculation than single inoculation. The plants inoculated either with *Rhizobium* or AM fungi and RP significantly increased the shoot length, dry weight of shoot, when compare to control. Result match with Badr *et al.* (2006) reported that dual inoculation with both rhizobia and mycorrhizae induced more significant increases in plant dry weight, as well as seed yield of studied legumes than inoculation with either VA mycorrhizae or *Rhizobium* alone. Khan *et al.* (2008) reported the dry weight of shoot and root without inoculation was 9.12 and 2.67 g whereas the shoot dry weight was 9.81, 10.61 and 12.64 g, while root weight was 2.88, 3.11 and 3.68 g, respectively when inoculated with *Gigaspora rosea*, *Glomus intraradices* + *Gigaspora rosea* and *Glomus etunicatum* + *Glomus intraradices*. The dual inoculations with *Glomus intraradices* + *Gigaspora rosea* and *Glomus etunicatum* + *Glomus intraradices* were significantly more effective than single inoculation (*Gigaspora rosea*).

And also according to Singh (2008) reported that application of VAM exhibited significantly higher dry matter accumulation than the application of other biofertilizer sources. The effect of different levels of rock phosphate with the association of *rhizobium* inoculation on the dry weight of shoot of legumes was found significant Table 55. El-Habbasha *et al.* (2005) noticed that increasing RP levels increased stem dry weights per plant of groundnut. Meshram *et al.* (2000) also found that among the P treatments, rock phosphate (RP) recorded the highest values for shoot dry weight (6.97 g

per plant) of chickpea. Our findings are in line with other workers (Abdulla & Pragatheswari *et al.*, 2004; Singh, 2008; 2010; Shehata *et al.*, 2010; Nazir *et al.*, 2011). Applying biofertilizer treatment also increased the dry weights however it was insignificant compared to the untreated control in both seasons summer and winter legumes. The interaction between biofertilizer (VAM & *Rhizobium*) and different levels of VAM+Rhiz. resulted in heaviest dry weights in comparison with applying each of them separately. With the increase of different levels of rock phosphate fertilizer increased the dry weight of shoot up to 11.25 kg P ha⁻¹ and above this level the shoot dry weight decreased. The lowest dry weight of shoot (1.93 g) was noted by control treatment. El-Habbasha *et al.* (2005) noticed that increasing P levels increased stem dry weights per plant of groundnut. Meshram *et al.* (2000) also found that among the P treatments, rock phosphate (RP) recorded the highest values for shoot dry weight (6.96 g per plant) of chickpea. Average dry weight of plant varied insignificantly from 0.95 to 1.26 g due to the treatment variations. Dry weight of root increased gradually with the increasing rate of P application up to 11.25 kg P ha⁻¹, but above this rate dry weight of root decreased. This result showed similarities with the findings of Singh *et al.* (2005) in lentil. Combined inoculation of VAM fungi and *Rhizobium* significantly increased dry weight of (52.79) and 38.58mg dry weight of nodules plant⁻¹ at flowering and at harvest stage or it might be due to the synergistic effect of *Rhizobium* and VAM fungi on root development. (Kumutha *et al.* 2004, Dudde & Raut, 2005). Khan & Kounsar (2000) and Perveen *et al.* (2002) also observed the similar type of results in their trails. Fatima *et al.*, in 2006 also found that the effect of growth was highly significant (α 0.05) with an increase in root/shoot dry and fresh weight in plants with mixture of *Rhizobium* inoculums with phosphorus on soybean. Combined inoculation of VAM fungi and *Rhizobium* significantly increased dry weight of (52.79 and 38.58mg dry weight of nodules plant⁻¹ at flowering and at harvest stage (Kumutha *et al.*, 2004; Dudde & Raut, 2005; Bhat *et al.*, 2010).

Table 55. Effect of Mycorrhizae, rhizobium (Rhz.) and rock phosphate (RP) inoculation on shoot dry weights of plant⁻¹ (g).P

Treatments	V ₁	V ₂	V ₃ n	<i>Macroptilum bracteatum</i>	<i>Pisum sativum</i>	<i>Desmodium dscendens</i>	V ₇	V ₈	V ₉	V ₁₀
Control	0.79	0.82	0.85	0.44	0.60	0.62	0.45	0.29	0.35	0.38
VAM	1.37	1.47	1.94	0.57	1.20	0.71	0.66	0.46	0.62	0.76
Rhz.	0.90	0.98	0.90	0.49	0.82	0.79	0.48	0.44	0.59	0.70
VAM+Rhz	1.77	1.92	1.99	0.61	1.27	1.00	0.71	0.59	0.72	0.81
RP₁ 15gm	0.69	0.74	0.82	0.47	0.69	0.44	0.66	0.38	0.45	0.55
MRP₁ gm	0.75	0.82	0.90	0.52	0.78	0.60	0.49	0.40	0.51	0.60
MRP₂gm	0.74	0.88	0.93	0.55	0.80	0.65	0.50	0.41	0.55	0.60
Total dry wt.(g)	7.01	7.63	8.33	3.66	6.16	4.81	3.95	2.97	3.79	4.4

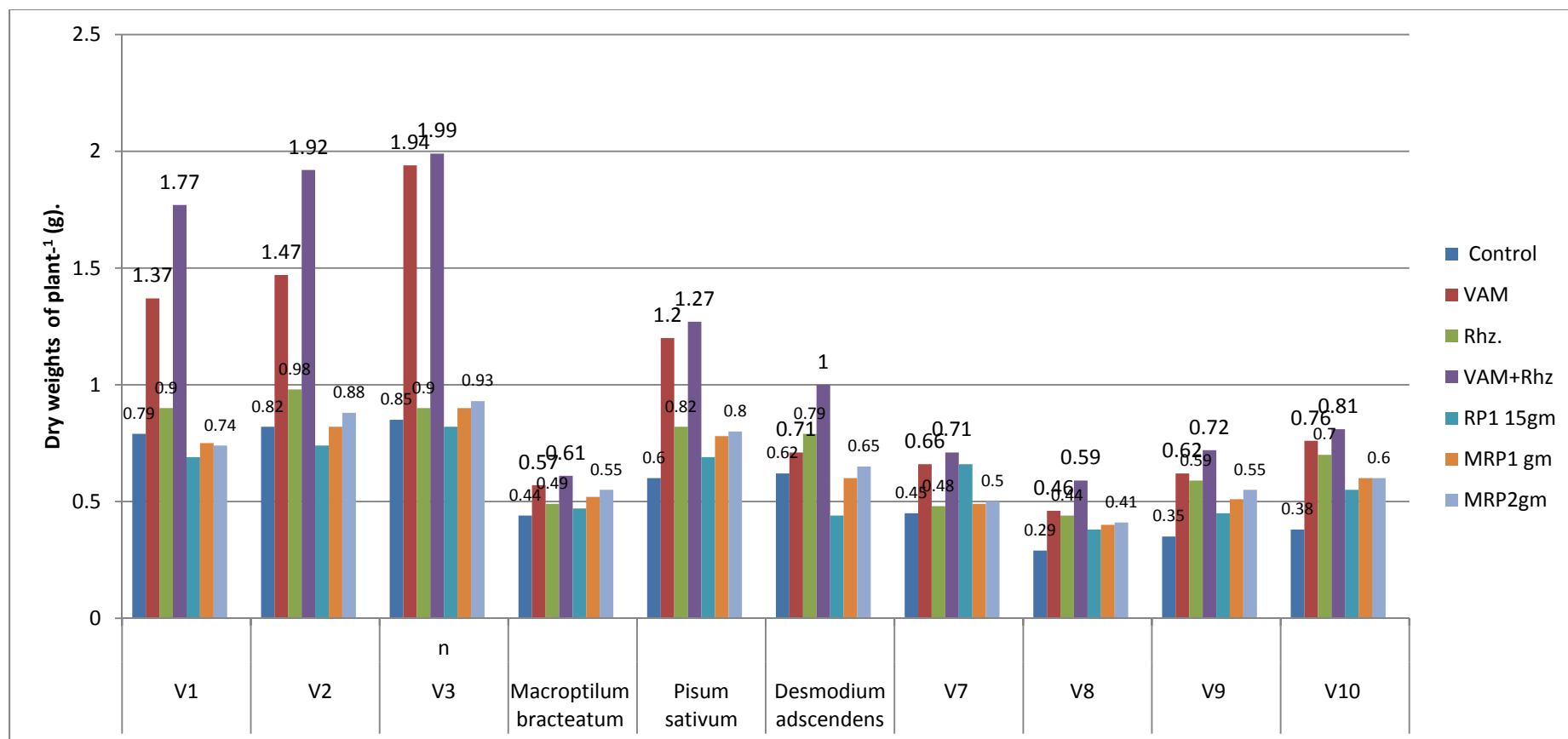


Fig.61.Effect of Mycorrhizae, rhizobium (Rhz.)and rock phosphate (RP) inoculation on shoot dry weights of plant⁻¹ (g).

4.5 Effect of VAM on dry matter and mycorrhizal dependency

Antunes *et al.* (2006) reported that mycorrhizal dependency, as a measure indicating how much a plant depends on AMF for its growth, is not necessarily a fixed value and therefore cannot be used as a definitive term. At flowering, the control plants weighed significantly less than the plants under any inoculation treatment. Results of VAM inoculation on dry matter and mycorrhizal dependency of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* are given in Table 56. The data pertaining to mycorrhizal dependency values of varieties and species given in Table 56. The results showed that V₁₀ and *Desmodium adscendens* followed by V₂, V₉, V₁, V₈, V₇, *Macroptilum bracteatum* and *Desmodium adscendens*, 50%, 50%, 44%, 43%, 42%, 37%, 32%, 23% and 13% respectively and V₁₀ and *Desmodium adscendens* were found to be more dependent on mycorrhiza and V₆ less dependent on mycorrhizal. Our result match with Sara *et al.* (2009) reported the species *M. lacerata*, *M. luisana*, *M. polyantha* and *M. texana* var. *filipes* had a high mycorrhizal dependency index indicating that plant growth was strongly increased by arbuscular mycorrhiza activity. Our results correlate with the findings of Singh (2008) who reported that application of VAM exhibited significantly higher dry matter accumulation and dependable than the application of other biofertilizer sources. Mycorrhizal dependency were determined at harvest stage. Our results correlate with the findings of Jagviret *al.* (2004) who reported that dry matter accumulation per plant increased with the advancement in age of the crop up to harvest in all treatments. The results of our investigation have showed that legumes were more dependent on mycorrhiza association for better growth in nutrient deficient soil. All studied legumes belong to family leguminous. The members of this family are generally believed to be more dependent on mycorrhizal symbiosis our results match with the findings of Sara *et al.* (2009) who reported that the species *M. lacerata*, *M. luisana*, *M. polyantha* and *M. texana* var. *filipes* had a high mycorrhizal dependency index indicating that plant growth was strongly increased by arbuscular mycorrhiza activity and Khalil *et al.* (1994) who studied the mycorrhizal dependency of soybean and corn, soybean had a higher mycorrhizal dependency than maize. The results showed that all varieties were found to be differ in their mycorrhizal dependency as also shown by Jain *et al.* (2008) reported the role of

VAM inoculation on mung bean (*Vignaradiata*) cultivars PS 16 and Pusa 105 with inoculation of VAM gave significantly higher yield and yield attributes in Pusa 105 as compared to PS 16 other workers also have the same statement (Jain *et al.*, 2007; Khan *et al.*, 2008; Abdulla&Khaliel, 2010). And like Vinicius *et al.* (2009) who reported that symbiosis formed by AM fungi can be deleterious to *Phaseolus vulgaris* growth depending on the plant variety and the symbionts involved. Our results confirmed with the findings of other workers, they observed that plant species and even cultivars of same species differ in their mycorrhizal dependency this difference is generally related with soil type, root geometry, plant growth rates, mycorrhizal species and soil phosphorus (Ortas *et al.*, 2001; Xavier & Germida., 2002; Bhat *et al.*, 2005; Vinicius *et al.*, 2009; Nazir *et al.*, 2011). The mycorrhizal plants under observation showed root and shoot dry weight. As we know that due to VAM inoculum the total biomass is again factor of plant height, leaves and root, which commonly resulted in to more dry weight. These results are in line with the observations of Mukherjee & Rai (2000), Giller (2001), Charitha & Reddy (2001), Xavier & Germind (2002), Bergero *et al.* (2003), Khan *et al.* (2005), Tufenkci *et al.* (2005), Khan *et al.* (2008), Rahman *et al.* (2008), Singh (2008), who stated that dry matter differences between mycorrhizal and non- mycorrhizal plants is due to benefits derived by plants from mycorrhizal association.

Table 56. Means of dry weight of five replicates Mycorrhiza dependency.

Varieties	Treatments	Means of Dry.wt of five replicates	M.D%
Niab-92 V₁*	M	1.37	42
	NM	0.79	
Niab-98 V₂**	M	1.47	44
	NM	0.82	
Niab-2006 V₃***	M	1.94	56
	NM	0.85	
<i>Macroptilum bracteatum</i>	M	0.44	23
	NM	0.57	
<i>Pisum sativum</i>	M	1.20	50
	NM	0.60	
<i>Desmodium adscendens</i>	M	0.71	13
	NM	0.62	
NARC-2008-2 V₇**	M	0.51	32
	NM	0.45	
NARC-2008-3 V₈*	M	0.46	37
	NM	0.29	
NARC-2008-4 V₉***	M	0.35	43
	M	0.62	
NARC-2002 V₁₀****	NM	0.38	50
	M	0.76	

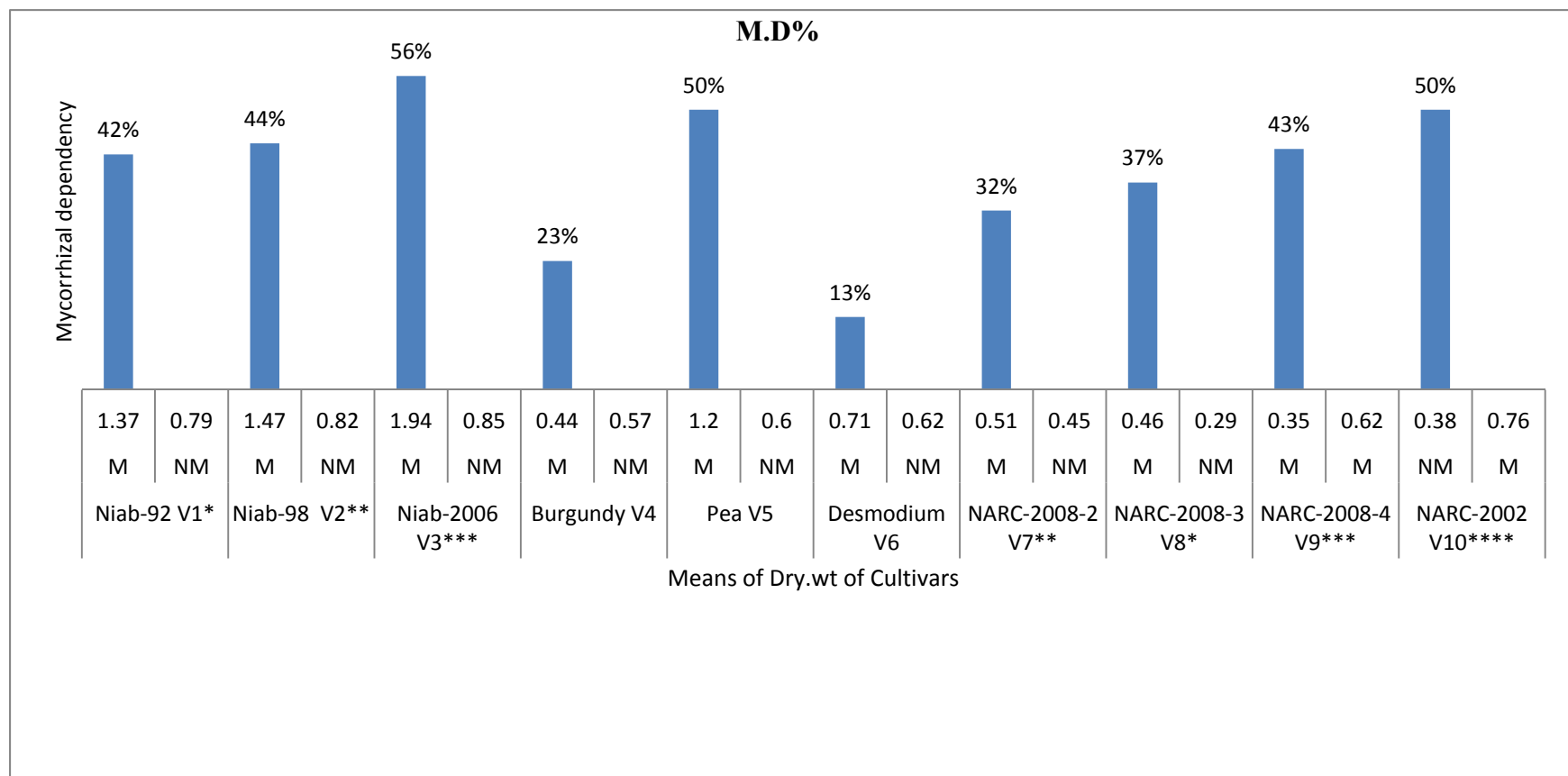


Fig. 62. Means of dry weight of five replicates Mycorrhizal dependency (MD).

4.6 Correlation between plant growth and yield parameters

The correlation between various mycorrhizal, rhizobial and rock phosphate plants growth parameters is presented in Tables 57-65. All the vegetative and reproductive growth parameters except pod length and number of seeds/pod showed highly positive correlation recorded at early vegetative growth stage. However, such correlations were lacking at later growth stages. The correlation between number of seeds/pod and pod length plant growth parameters was invariably insignificant at all the growth stages. The results of earlier studies regarding the correlation between plant growth and yield parameters are contradictory. In a recent study, Javaid & Riaz (2008) reported a significant positive correlation of root and shoot biomasses with different parameters of arbuscular and vesicular colonization in maize. Similarly, Xavier & Germida (2002) have reported a positive correlation between AM colonization of roots and total shoot dry matter production in lentil (*Lens culinaris* cv. Laird). By contrast, according to Al-Karaki & Clark (1998) enhanced plant growth may not always be related to degree of root mycorrhizal colonization in some plants.

Table 57. Correlation between Plant height at vegetative stage and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	PH1	LV1	0.306*
Niab-98 V ₂ **	PH1	PH2	0.190*
Niab-2006 V ₃ ***	PH1	LV2	0.436*
Burgundy	PH1	FL2	0.465*
Pea	PH1	PH3	0.254*
Desmodium	PH1	LV3	0.297*
NARC-2008-2 V ₇	PH1	Number of Pod/plant	0.593*
NARC-2008-3 V ₈	PH1	Pod length	-0.192ns
NARC-2008-4 V ₉ *	PH1	Number of Seed/pod	-0.223ns

*, P<0.05 ns=non significant

Table 58. Correlation between Plant height at flowering stage and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	PH2	PH1	-----
Niab-98 V ₂ **	PH2	PH2	-----
Niab-2006V ₃ ***	PH2	LV2	0.028
Burgundy	PH2	FL2	0.110
Pea	PH2	PH3	0.342
Desmodium	PH2	LV3	0.022
NARC-2008-2V ₇	PH2	Number of Pod/plant	0.047
NARC-2008-3V ₈	PH2	Pod length	-0.502ns
NARC-2008-4V ₉ *	PH2	Number of Seed/pod	0.670ns

*, P<0.05 ns=non significant

Table 59. Correlation between number of leaves at vegetative stage and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	LV1	PH1	-----
Niab-98 V ₂ **	LV1	PH2	0.018
Niab-2006V ₃ ***	LV1	LV2	0.875
Burgundy	LV1	FL2	0.745
Pea	LV1	PH3	-0.245ns
Desmodium	LV1	LV3	0.925
NARC-2008-2V ₇	LV1	Number of Pod/plant	0.729
NARC-2008-3V ₈	LV1	Pod length	-0.642ns
NARC-2008-4V ₉ *	LV1	Number of Seed/pod	-0.689ns

*, P<0.05 ns=non significant

Table 60. Correlation between leaves at flowering stage and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	LV2	PH1	-----
Niab-98 V ₂ **	LV2	PH2	-----
Niab-2006V ₃ ***	LV2	LV2	-----
Burgundy	LV2	FL2	0.747
Pea	LV2	PH3	-0.291ns
Desmodium	LV2	LV3	0.918
NARC-2008-2V ₇	LV2	Number of Pod/plant	0.755
NARC-2008-3V ₈	LV2	Pod length	-0.666ns
NARC-2008-4V ₉ *	LV2	Number of Seed/pod	-0.722ns

*, P<0.05 ns=non significant

Table 61. Correlation between leaves at flowering stage and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	LV3	PH1	----
Niab-98 V ₂ **	LV3	PH2	----
Niab-2006V ₃ ***	LV3	LV2	----
Burgundy	LV3	FL2	----
Pea	LV3	PH3	----
Desmodium	LV3	LV3	----
NARC-2008-2V ₇	LV3	Number of Pod/plant	0.715
NARC-2008-3V ₈	LV3	Pod length	-0.631ns
NARC-2008-4V ₉	LV3	Number of Seed/pod	-0.701ns

*, P<0.05 ns=non significant

Table62. Correlation between flowers per plant and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	FL2	PH1	---
Niab-98 V ₂ **	FL2	PH2	---
Niab-2006V ₃ ***	FL2	LV2	---
Burgundy	FL2	FL2	---
Pea	FL2	PH3	-0.133ns
Desmodium	FL2	LV3	0.758
NARC-2008-2V ₇	FL2	Number of Pod/plant	0.805
NARC-2008-3V ₈	FL2	Pod length	-0.606ns
NARC-2008-4V ₉	FL2	Number of Seed/pod	-0.624ns

*, P<0.05 ns=non significant

Table 63. Correlation between plant height at fruiting stage and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	PH3	PH1	-----
Niab-98 V ₂ **	PH3	PH2	-----
Niab-2006V ₃ ***	PH3	LV2	-----
Burgundy	PH3	FL2	-----
Pea	PH3	PH3	-----
Desmodium	PH3	LV3	-0.290ns
NARC-2008-2 V ₇	PH3	Number of Pod/plant	-0.105ns
NARC-2008-3V ₈	PH3	Pod length	0.549*
NARC-2008-4V ₉	PH3	Number of Seed/pod	0.611*

*, P<0.05 ns=non significant

Table 64. Correlations between pod per plant and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ *	#Pod/pl	PH1	-----
Niab-98 V ₂ **	#Pod/pl	PH2	-----
Niab-2006V ₃ ***	#Pod/pl	LV2	-----
Burgundy	#Pod/pl	FL2	-----
Pea	#Pod/pl	PH3	-----
Desmodium	#Pod/pl	LV3	-----
NARC-2008-2V ₇	#Pod/pl	Number of Pod/plant	-----
NARC-2008-3V ₈	#Pod/pl	Pod length	-0.591ns
NARC-2008-4V ₉	#Pod/pl	Number of Seed/pod	-0.602ns

*, P<0.05 ns=non significant

Table 65. Correlations between pod length and growth parameters at three different stages.

Varieties			Correlation (r)
Niab-92 V ₁ Pod length	PL	PH1	-----
Niab-98 V ₂	PL	PH2	-----
Niab-2006V ₃	PL	LV2	-----
Burgundy	PL	FL2	-----
Pea	PL	PH3	-----
Desmodium	PL	LV3	-----
NARC-2008-2V ₇	PL	Number of Pod/plant	-----
NARC-2008-3V ₈	PL	Pod length	-----
NARC-2008-4V ₉ *	PL	Number of Seed/pod	0.808*

*, P<0.05 ns=non significant

III. NUTRITION EVALUATION

4.7 Effect of AMF-rhizobia and Rockphosphate-AMF interaction on chemical composition

Proximate Composition

The objective of the experiment was to study the effect of inoculation proximate analysis. It is of interest to notice that the dual inoculation of rhizobium and VAM not only increased seed yield, but also improved seed nutritional value. Most of the *rhizobium* strains, mycorrhizal and rock phosphate significantly increased yield, protein, crude fibre, and dry matter etc. The proximate composition of four important legumes *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀), varieties were studied in order to evaluate their nutritional performance. Significant ($P < 0.05$) variations existed among the legumes with respect to their proximate composition. Five legumes with their varieties, each with three replicates, of protein content, dry matter, ash, moist content, carbohydrate and fats were selected. Moreover, the measurement of some proximate profiles such as protein contents, carbohydrate, lipids, moisture contents and ash percentage is often necessary to ensure that they meet the requirements of food regulators Omomowo *et al.* (2009). Inoculation significantly ($P < 0.05$) enhanced the ash, crude protein and the crude fat contents of cowpea seeds. (Omomowo *et al.*, 2006) had reported a similar result of using inoculation treatments with *Glomus mosseae* and / or *Bradyrhizobium japonicum* to increase the seed weight and proximate composition of cowpea, and that they are promising microbial inoculants for the improvement of the quality of leguminous crops, especially in the tropics.

Crude protein (CP)

Crude protein, referring to all the nitrogenous compounds present in forage feed, is reliable source of overall nutritional status. They are directly related to digestibility, vitamin, calcium and phosphorus contents. These all features decline with low crude protein to almost deficient levels (Ganskopp & Bohner, 2001). Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on crude protein of *Vigna radiata* (V₁-V₃),

Macroptilum bracteatum, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris*(V₇-V₁₀), varieties following seven treatments are given in Tables72-78. It is evident from data that the treatment of biofertilizer enhanced the crude protein content compared to the synthetic fertilizer and control.

The ranges of CP contents of V₁-V₃, V₄, V₅, V₆and V₇-V₁₀ were 21.20±0.14–25.1±0.03%, 9.23±0.17–12±0.03%, 19.8±0.09–24.04±0.03%, 18.14±0.04–20.06±0.01% and 22.6±0.11–25.52±0.02 %, respectively over the control.VAM, *Rhizobium* and Rock phosphate dual inoculations significantly ($P \leq 0.05$) increased protein content over the uninoculated treatment.

ANOVA also represented the variance among species and between treatments highly significant for crude protein. ANOVA (Table66) of crude protein contents are shown in Tables72-78. ANOVA showed that varieties, Interaction between varieties and treatments and the effect of treatments were significantly different regarding crude protein content. The ANOVA showed that varieties were ($P>0.000$) or (100%) highly significantly different regarding crude protein at harvesting stage. Interaction between varieties and treatments was ($P>0.0001$) or (100%) highly significant. Omomowo *et al.*(2006, 2009) had reported a similar result of using inoculation treatments with *Glomus mosseae* and / or *Bradyrhizobium japonicum* to increase the seed weight and proximate composition of cowpea, and that they are promising microbial inoculants for the improvement of the quality of leguminous crops, especially in the tropics.

There were great variation among all cultivars and treatments our result in line with Zaidi & Saghir (2006) reported that Protein contents in seeds varied between 18 and 24% in inoculated chickpea. Our results also agree with Erdal *et al.* (2008) reported that single, dual, and triple inoculations with *Rhizobium*, significantly increased total biomass yield, and seed protein content compared with the control treatment. The results show the comparative protein content of different legumes. It is evident that *Lens culinaris Medic.*contained the maximum amount of protein (25.52±0.02 %), followed by *Vigna radiata* (25.1±0.03%),*Desmodium adscendens* (24.04±0.03%), *Pisum sativum* L. (24.04±0.03%) and*Macroptilum bracteatum* (12±0.03%). Result correlate with the findings of Ufuk & Aşir (2010), who observed that lentil (*Lens culinaris* Medik.) is one

of the most important crops with 4.4% protein, 1.8 oil, 41-50.8% carbohydrates, 21.4 fibrous similarly significant increases in seed protein content due to bacterial inoculation supported the hypothesis that biological nitrogen fixation by the *Rhizobium* and PGPR-root associations could be responsible for the observed higher N uptake of inoculated plants (Kantar *et al.*, 2003; Ozturk *et al.*, 2003; Erdal *et al.*, 2008). The result corresponds with those of to be a good source of crude protein as previous works of Srivastava & Ali (2004), *Vigna umbellata* (Rajaram & Janardhanan, 1990) and *Canavalia virosa* (Thangadurai, *et al.*, 2001). Lentils (*Lens culinaris*) are rich sources of complex carbohydrates, protein, dietary fiber, vitamins, minerals and high energetic value (Costa *et al.*, 2006). There is great variation on the influence of treatment on studied legumes some time rarely rhizobium are efficient then other treatment shown in tables. Our result match with the Bhat *et al.* (2010) that crude protein content was influenced significantly due to the inoculation of *Rhizobium*. The *Rhizobium* inoculation recorded 3.82 percent and 2.68 while the crude protein and water soluble protein content of cultivars were lower than that reported by Cone *et al.* (2002) and Wang & Daun (2004). Our result also match with Neveen *et al.* (2008) report that fungal infection and rhizobial inoculation either alone or in combination with 50% or 75% of the recommended doses of N and/or P fertilizers increased protein, and total carbohydrate on both cultivars as compared to uninoculated plants. According to Elsheikh & Ahmed (2000) *rhizobium* inoculation and/or intercropping treatments significantly increased the ash, crude fibre, fat, protein content, and moisture and tannin contents compared to the uninoculated monocrop control. There was a significant strain x cultivar interaction, Moreover, inoculation enhanced the symbiotic properties of legumes plants and better growth and production were obtained by biofertilizers application. *Lens culinaris* is one of the most important crops with 4.4% protein, 1.8 oil, 41-50.8% carbohydrates, 21.4 fibrous, high percentage of other mineral nutrients and unsaturated linoleic and oleic acid for human consumption (Ozdemir, 2002). The results revealed that protein contents not only varied among the species but also between the different treatments given to the plants. Our result agrees with Omomowo *et al.* (2009) who reported that result showed that there were significant effects on the proximate contents of cowpea seeds due to inoculated treatments and others reports that *Rhizobium* inoculation has been to increase seed protein content

of soybean (Regitano, *et al.*, 1995), faba bean (Babiker *et al.*, 1995 & Elsheikh, 1998) and fenugreek (Abdelgani *et al.*, 1998). Sheraz *et al.* (2010) reported that mycorrhizal associations (VAM) in alleviating toxicity, increasing N, P and micronutrient uptake, maintaining soil structure by the production specific protein called “Glomulin. Mature plants usually contained high CF than young plants, It was observed in the present study as plants had high CF contents at fruiting stage our result in line with Murthy (2011) investigation that mature seed samples were analyzed for proximate composition, the seed samples contained higher amount of crude protein, crude fat and ash. The calorific value of 100g dry matter of seed material was 1783.92 kJ/100 Dm. The hyphae of AMF can also take up amino acids (Hawkins *et al.*, 2000; Govindarajulu *et al.*, 2005; Jin *et al.*, 2005). This corroborates the findings of (Martins *et al.*, 2003) who reported that biological nitrogen fixation associated with cowpea is able to improve plant growth and grain production.

Table 66. ANALYSIS OF VARIANCE

Crude protein contents						
K	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	6	56.442	9.407	101.0102	0.0000
4	Factor B	9	5829.685	647.743	6955.3595	0.0000
6	AB	54	318.523	5.899	63.3380	0.0000
-7	Error	280	26.076	0.093		
Total		349	6230.725			

Coefficient of Variation: 1.38%

Moisture contents

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on moisture contents of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀), varieties following seven treatments are given in Tables 72-78. It is evident from data that the treatment of biofertilizer enhanced the plant moisture contents compared to the control.

ANOVA Table 67 of moisture contents are shown in Tables 72-78. ANOVA showed that varieties, Interaction between varieties and treatments and the effect of

treatments were significantly different regarding moisture content. The ANOVA showed that varieties were ($P>0.000$) or (100%) highly significantly different regarding moisture content at harvesting stage. Interaction between varieties and treatments was ($P>0.0001$) or (100%) highly significant.

The moisture contents in the analyzed species varied in V_1 - V_3 (*Vigna radiata*) (7 ± 0.03 – 9.82 ± 0.02 %) , in *Macroptilum bracteatum* ranged from 7.66 ± 0.05 – 8.9 ± 0.03 % in *Pisum sativum* 7.3 ± 0.05 – 9.42 ± 0.07 % in *Desmodium adscenden*, 7.22 ± 0.05 - 9.58 ± 0.04 and in V_7 - V_{10} (*Lens culinaris*) ranged from $5.72\pm0.02\%$ to $9.7\pm0.03\%$. The overall percentage of moistures composition was maximum in *Lens culinaris* (the lowest moisture percentage was recorded in *Macroptilum bracteatum*). The moisture content of all cultivars was affected by the *Vesicular arbuscular mycorrhizal*, *Rhizobium* and Rockphosphate inoculation and application and even by cultivars. Moisture content can vary according to climatically conditions. There are reports of negative correlations between dry matter and moisture contents (Amir *et al.*, 2007). The results revealed that moisture contents not only varied among the species but also between the different treatments given to the plants. Hussain *et al.* (2010) also stated that moisture content vary in different species. Das *et al.* (2009) and Hanif *et al.* (2006) concluded that green leafy vegetables had higher moisture content. There is great variation between summer and winter studied legumes which are shown in tables our result match with report of Palta *et al.* (2010), who reported that especially accumulation of moisture, ash, total nitrogen, total protein, water soluble protein, oil and fiber varied speedy with time and similarly to Stacey *et al.* (2006) who also explained that chemical composition varied with time. However, accumulation patters of chemical matters needs to be examined carefully Ufuk & Aşir (2010). The results revealed that moisture contents not only varied among the species and treatments but also different because of more leaves and shoot of the plants or broad leaves and small leaves as shown in Tables 44-54. Hussain *et al.* (2010) also stated that moisture content vary in different species. Das *et al.* (2009) and Hanif *et al.* (2006) concluded that green leafy vegetables had higher moisture content.

Table 67. ANALYSIS OF VARIANCE

Moisture contents						
K	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	6	37.632	6.272	200.0175	0.0000
4	Factor B	9	255.102	28.345	903.9301	0.0000
6	AB	54	222.949	4.129	131.6664	0.0000
-7	Error	280	8.780	0.031		
Total		349	524.463			

Coefficient of Variation: 2.26%

CrudeFat contents

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on fat contents of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀), varieties following seven treatments are given in Tables (72-78) It is evident from data that the treatment of biofertilizer and fertilizer enhanced the crudefat content compared to the control.

ANOVA also represented the variance among species and between treatments highly significant for fat contents. ANOVA of crudefat content are shown in tables (72-78). ANOVA showed that varieties, Interaction between varieties and treatments and the effect of treatments were significantly different regarding crudefat content. The ANOVA showed that varieties were ($P > 0.000$) or (100%) highly significantly different regarding crudefat content at harvesting stage. Interaction between varieties and treatments was ($P > 0.0001$) or (100%) highly significant. The ranges of fat contents of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀) were 1.12 ± 0.02 – $4.14 \pm 0.02\%$, 2.56 ± 0.02 – $3.06 \pm 0.02\%$, 2.14 ± 0.02 – $3.42 \pm 0.02\%$, 1.8 ± 0.02 – $2.94 \pm 0.02\%$, and 1.84 ± 0.02 – $2.86 \pm 0.01\%$, respectively over the control (Table 1a-5a). Fat contents of different legumes cultivars were significantly ($P \leq 0.05$) increased with *Vesicular arbuscular mycorrhizal* and *rhizobium* strains as compared to rockphosphate alone. All cultivars varied greatly in their fat content. Generally, the results are in good agreement with those reported of Bhaty & Christison (1984) and Elsheikh (1998) that fats are important dietary

constituents not only because of their high energy value, but also because of the vitamins and the essential fatty acids. There are significant different appeared among varieties. The fat content was lower as required and there was a great vairabilty result agree with the finding of Henshaw (2008), who explained that the content of fat was the least discriminating variable. The low fat content in cowpea is an advantage during processing to flour, since unlike other legumes such as soyabean there is no need for a defatting stage in flour production.

Table 68. ANALYSIS OF VARIANCE

CrudeFat contents						
K	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	6	10.770	1.795	92.7267	0.0000
4	Factor B	9	20.517	2.280	117.7669	0.0000
6	AB	54	43.749	0.810	41.8539	0.0000
-7	Error	280	5.420	0.019		
	Total	349	80.456			

Coefficient of Variation: 5.64%

Crude fibers (CF)

Fiber is an important constituent of balance diet that decreases blood cholesterol level, heart risks, colon cancer and diabetes (Ishida *et al.*, 2000). The RDA values of fibers for children are 19-25% and for lactating mother is 29 %. Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on crude fibers of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris*(V₇-V₁₀), varieties following seven treatments are given in Tables 72-78. It is clear from data that the treatment of biofertilizer enhanced the crude fiber content compared to the control, ANOVA Table 69 of crude fiber content are shown in Tables 72-78. ANOVA showed that varieties, Interaction between varieties and treatments and the effect of treatments were significantly different regarding crude fiber content. The ANOVA showed that varieties were (P>0.000) or (100%) highly significantly different regarding crude protein content at harvesting stage. Interaction between varieties and treatments was (P>0.0001) or (100%) highly significant. Fiber is

an important constituent of balance diet that decreases blood cholesterol level, heart risks, colon cancer and diabetes (Ishida *et al.*, 2000). The values of fibers for children are 19-25% and for lactating mother is 29 %. In the present study, generally it varies ranges from 6.14 ± 0.02 to 24.6 ± 0.11 . The results presented in Tables 1a-5a show that there were significant differences between cultivars in crude fiber content in green mung bean V_1-V_3 ranged from 7.57 ± 0.03 to 14.5 ± 0.08 mg/100, in burgundy from 11.98 ± 0.05 to 20.02 ± 0.02 mg/100 g, in pea ranged from 1.06 ± 0.01 to 2.54 ± 0.24 mg/100 g, in desmodium from 5.24 ± 0.02 to 6.84 ± 0.02 mg/100 g, and in lentil V_7-V_{10} ranged from 6.14 ± 0.02 to 24.6 ± 0.11 mg/100 g. ANOVA (Table 69) showed that varieties and the effect of treatments were significantly different. Maximum uptake of nutrient was attained at mycorrhizal and rhizobium combined inoculated plants than control. Our result matches with Sher *et al.* (2004), who reported that inoculation with *Rhizobium* + PSB resulted in higher seed and straw yields, protein content, and crude fiber compared to no inoculation and single inoculation with *Rhizobium* or PSB. All legumes cultivars varied greatly in their crude fiber contents shown in Tables 72-78. Inoculation with *Vesicular arbuscular mycorrhizal* and rhizobium strains increased the crude fiber content; this variation may be attributed to climatic and varietal differences. All of the six lens cultivars were noted to be poor in crude fat (Kaya & Yalçın, 1999). There are significant differences among cultivars according to crude fiber. *Lens culinaris* is one of the most important crops with 4.4% protein, 1.8 oil, 41-50.8% carbohydrates, 21.4 fibrous Ufuk & Aşır (2010).

Table 69. ANALYSIS OF VARIANCE

Crude fiber contents						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	6	262.550	43.758	354.6792	0.0000
4	Factor B	9	6485.747	720.639	5841.0763	0.0000
6	AB	54	2580.171	47.781	387.2845	0.0000
-7	Error	280	34.545	0.123		
Total		349	9363.012			

Coefficient of Variation: 3.15%

Carbohydrate contents

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on carbohydrate contents of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀), varieties following seven treatments are given in Tables 72-78. It is evident from data that the treatment of biofertilizer enhanced the carbohydrate content compared to the control.

ANOVA Table 70 of carbohydrate contents are shown. ANOVA showed that varieties, Interaction between varieties and treatments and the effect of treatments were significantly different regarding carbohydrate content. The ANOVA showed that varieties were ($P > 0.000$) or (100%) highly significantly different regarding carbohydrate content at harvesting stage. Interaction between varieties and treatments was ($P > 0.0001$) or (100%) highly significant. The results show that there were significant differences between cultivars in carbohydrate content in green mung bean V₁-V₃ ranged from 74.54 ± 0.05 to 79.08 ± 0.10 mg/100, in burgundy from 33.64 ± 0.03 to 48.3 ± 0.08 mg/100 g, in pea ranged from 62.06 ± 0.03 to 66.42 ± 0.05 mg/100 g, in desmodium from 53.74 ± 0.02 to 57.66 ± 0.09 mg/100 g, and in lentil V₇-V₁₀ ranged from 37.82 ± 0.02 to 54.44 ± 0.05 mg/100 g. There was an increasing trend of carbohydrates from variety to variety in all the analysed species. Carbohydrate contents were usually higher in all studied legumes shown in Tables 72-78. Among these plants carbohydrates were the highest in V₁-V₃ followed by pea, desmodium, V₇-V₁₀ and burgundy. Our results are supported by Ufuk & Aşir (2010), who also reported that total carbohydrates ranged from 42.63 to 49.55%. Carbohydrates were the highest in Malazgirt 89 followed by Emre 20. This variation may be attributed to climatic and varietal differences.

ANOVA showed that varieties and the effect of treatments were significantly different. Maximum uptake of nutrient was attained at mycorrhizal and *rhizobium* combined inoculated plants than control. Our result matches with Harrison (2005) reported that this mutualistic association provides the fungus with relatively constant and direct access to carbohydrates, such as glucose and sucrose supplied by the plant. Muhammad *et al.* (2006) also reported that chick pea seeds are more palatable, nutritive, digestible and non-flatulent than other pulses grown in country. Its seeds contain 24.2% protein, 1.3% fat and 60.4% carbohydrates, calcium and phosphorous are measured as 118 mg and 340

mg per 100 g of seeds, respectively. Sheteawi & Tawfik (2007) reported that commonly slightly higher amounts of total carbohydrates, lipid and total crude protein contents were obtained in seeds of plants irrigated every 5 d than those of 10 d drying cycle while they were more or less comparable for the biofertilized and nonfertilized plants. Murthy (2011) investigated that mature seed samples were analyzed for proximate composition, the seed samples contained higher amount of crude protein, crude fat and ash. The calorific value of 100g dry matter of seed material was 1783.92 kJ/100 Dm. AMF can arguably be involved directly in the mineralization of organic residues (Talbot *et al.*, 2008), at least to some extent. Lentil (*Lens culinaris* Medik.) is one of the most important crops with 4.4% protein, 1.8 oil, 41-50.8% carbohydrates, 21.4 fibrous Ufuk & Aşir (2010).

Table 70. **ANALYSIS OF VARIANCE**
Carbohydrate contents

K	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	6	367.356	61.226	1104.5921	0.0000
4	Factor B	9	57504.902	6389.434	115273.1094	0.0000
6	AB	54	3239.574	59.992	1082.3302	0.0000
-7	Error	280	15.520	0.055		
Total		349	61127.352			

Coefficient of Variation: 0.40%

Ash content (total minerals)

Results of VAM, RHZ, RHZ +VAM, RP and VAM+RP inoculation on ash contents of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* (V₇-V₁₀), varieties following seven treatments are given in Tables 72-78. It is evident from data that the treatment of biofertilizer and fertilizer (RP) enhanced the ash content compared to the control.

ANOVA Table 71 of ash content are shown in Tables 72-78. ANOVA showed that varieties, Interaction between varieties and treatments and the effect of treatments were significantly different regarding ash content. The ANOVA showed that varieties were ($P > 0.000$) or (100%) highly significantly different regarding ash content at harvesting stage. Interaction between varieties and treatments was ($P > 0.0001$) or (100%) highly

significant. The ranges of ash contents of V₁-V₃, *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and V₇-V₁₀ were 2.76±0.02–3.74±0.04 %, 18.02±0.04–24.26±0.04 %, 7.34±0.03–9.16±0.03% and 1.34±0.02 –3.84±0.02%, respectively over the control (Table 72-78) ash content increased with the VAM alone or rhizobium and VAM fungi inoculation, our result agree with Khalil & Durani, (1989) cowpea inoculated with VAM generally contains a high amount of ash. and VAM fungi even with rock phosphate also increased the value of ash but rhizobium and rock phosphate alone decreased their content our result in line with the Elsheikh, & Elzidany (1997a) the ash content of faba bean seeds was significantly increased with chicken manure and sulphur treatments but not with Rhizobium strains. Murthy (2011) investigated that mature seed samples contained higher amount of crude protein, crude fat and ash. The calorific value of 100g dry matter of seed material was 1783.94 kJ/100 Dm. There was a great difference in ash between summer and winter crops ash. Our results agree with Palta *et al.* (2010) whom achieved similar results. Karadavut & Palta (2010) stated that chemical composition varied in different locations. Stacey *et al.* (2006) explained that chemical composition varied with time. The founded variation in seed chemical composition among cultivars in the present study could be due to genetic differences (Ereifej *et al.*, 2001; Farshadfar & Farshadfar, 2008).

Table 71. ANALYSIS OF VARIANCE

Ash contents						
K		Degrees of	Sum of	Mean	F	
Value	Source	Freedom	Squares	Square	Value	Prob
2	Factor A	6	20.235	3.373	143.9241	0.0000
4	Factor B	9	10953.656	1217.073	51939.3662	0.0000
6	AB	54	212.834	3.941	168.2009	0.0000
-7	Error	280	6.561	0.023		
Total	349	11193.287				

Coefficient of Variation: 2.74%

Table 72. Proximate Composition of three *Vigna radiata* affected by inoculation with *Rhizobium* and/or Mycorrhiza and Rock phosphate.

Varieties	Treatment	Moisture (%)	Ash (%)	Ether Extract (%)	Crude Fibers (%)	Crude Protein (%)	Carbohydrate (%)
Niab-92V₁	Control	9.36±0.09	2.76±0.02	2.46±0.02	14.5±0.08	25.1±0.03	74.74±0.03
	VAM	8.74±0.04	3.43±0.01	1.96±0.01	11.2±0.01	22.22±0.03	77.62±0.04
	RHZ	8.18±0.03	3.56±0.03	1.86±0.04	11.36±0.02	23.52±0.02	76.34±0.03
	RHZ+VAM	8.3±0.02	3.8±0.03	3.22±0.04	7.86±0.01	21.20±0.14	79.08±0.10
	RP	9.16±0.02	3.62±0.04	2.28±0.04	10.16±0.02	23.96±0.02	75.94±0.03
	MRP₁	9.52±0.04	3.74±0.04	2.18±0.03	10.22±0.02	24.08±0.03	75.66±0.04
	MRP₂	9.46±0.06	3.12±0.02	2.38±0.04	8.72±0.02	23.62±0.04	76.18±0.03
Niab-98V₂	Control	8.82±0.05	2.78±0.03	3.16±0.04	12.6±0.03	24.26±0.02	75.62±0.04
	VAM	9.6±0.04	3.18±0.03	2.84±0.04	12.32±0.03	22.76±0.07	77.06±0.02
	RHZ	9.82±0.02	2.78±0.04	2.62±0.04	14.8±0.04	25.16±0.05	74.7±0.05
	Rhz+VAM	7.68±0.03	2.94±0.06	2.4±0.02	11.64±0.05	24.64±0.03	75.3±0.05
	RP	6.66±0.06	3.04±0.01	3.62±0.07	8.66±0.04	24.42±0.02	75.5±0.08
	MRP₁	7±0.03	3.6±0.02	1.96±0.02	12.32±0.05	21.86±0.02	78.6±0.05
	MRP₂	9.76±0.04	3.46±0.01	2.28±0.04	12.12±0.02	21.48±0.03	78.38±0.03
Niab-2006V₃	Control	7.76±0.03	3.06±0.02	3.04±0.05	7.57±0.03	25.38±0.02	74.54±0.05
	VAM	9.24±0.05	3.56±0.02	2.8±0.04	10.52±0.05	25.06±0.02	74.82±0.04
	RHZ	8.56±0.03	3.2±0.03	2.44±0.02	8.82±0.03	24.12±0.02	75.66±0.07
	RHZ+VAM	7.64±0.05	3.66±0.08	1.56±0.02	8.54±0.02	24.04±0.03	75.7±0.03
	RP	8.76±0.03	3.62±0.03	1.12±0.03	7.64±0.04	24.46±0.03	75.18±0.04
	MRP₁	9.58±0.04	3.12±0.02	1.12±0.02	9.66±0.02	23.64±0.02	75.4±0.10
	MRP₂	9.26±0.05	4.14±0.02	4.14±0.02	8.08±0.04	23.32±0.06	76.3±0.08

All values mean ± SEM of 5 determinations (replicates)

Table 73. Proximate composition of *Macroptilum bracteatum* affected by inoculation with *Rhizobium* and/or Mycorrhiza and Rock phosphate.

Treatment	Moisture (%)	Ash (%)	Ether Extract (%)	Crude Fibers (%)	Crude Protein (%)	Carbohydrate
Control	7.66±0.05	21.44±0.05	2.56±0.02	12.3±0.05	9.23±0.17	45.28±0.05
VAM	8.9±0.03	24.26±0.04	3.06±0.02	11.98±0.05	10.78±0.10	36.02±0.03
RHZ	8.84±0.02	19±0.04	2.72±0.04	12.6±0.02	10.94±0.02	45.04±0.04
RHZ+VAM	7.92±0.03	20.08±0.02	2.68±0.04	17.3±0.08	12.04±0.04	38.24±0.08
RP	7.82±0.03	21.42±0.04	2.98±0.02	15.1±0.02	12±0.03	40.16±0.02
MRP ₁	8.16±0.04	23.2±0.02	2.96±0.02	20.02±0.02	11±0.03	33.64±0.03
MRP ₂	8.5±0.05	18.02±0.04	3.08±0.03	12.06±0.03	9.92±0.04	48.3±0.08

All values mean ± SEM of 5 determinations (replicates)

Table 74. Proximate composition of *Pisum sativum* affected by inoculation with *Rhizobium* and/or Mycorrhiza and Rock phosphate.

Treatment	Moisture (%)	Ash (%)	Ether Extract (%)	Crude Fibers (%)	Crude Protein (%)	Carbohydrate (%)
Control	7.76±0.06	8.6±0.11	3.42±0.02	1.06±0.01	19.8±0.09	66.42±0.05
VAM	7.48±0.07	8.24±0.02	3.1±0.01	2.18±0.03	21.6±0.11	64.32±0.05
RHZ	9.42±0.07	8.46±0.01	2.86±0.02	1.56±0.02	24.04±0.03	62.82±0.03
RHZ+VAM	8.66±0.04	8.84±0.02	3±0.02	1.86±0.02	23.56±0.03	62.52±0.04
RP	7.3±0.05	9.16±0.03	2.7±0.02	2.54±0.24	22.7±0.02	62.06±0.03
MRP ₁	7.74±0.05	7.82±0.02	2.14±0.02	2.26±0.05	22.6±0.03	64.78±0.04
MRP ₂	8.62±0.03	7.34±0.03	3.1±0.02	1.08±0.02	21.64±0.12	66.2±0.03

All values mean ± SEM of 5 determinations (replicates)

Table 75. Proximate composition of *Desmodium adscendens* affected by inoculation with *Rhizobium* and/or Mycorrhiza and Rock phosphate.

Treatment	Moisture (%)	Ash (%)	Ether Extract (%)	Crude Fibers (%)	Crude Protein (%)	Carbohydrate (%)
Control	7.22±0.05	7.24±0.07	2.02±0.02	5.96±0.01	19.96±0.01	56.7±0.05
VAM	8.08±0.02	7.94±0.02	1.98±0.01	5.5±0.02	18.14±0.04	57.66±0.09
RHZ	9.58±0.04	7.72±0.04	2.56±0.01	5.98±0.02	19.84±0.02	53.74±0.02
RHZ+VAM	9.42±0.03	8±0.02	2.94±0.02	5.24±0.02	18.34±0.01	55.58±0.07
RP	8.2±0.03	7.92±0.03	1.96±0.02	5.4±0.02	20.06±0.01	55.98±0.03
MRP₁	7.72±0.04	7.6±0.02	1.8±0.02	6.84±0.02	19.22±0.03	56.18±0.03
MRP₂	9.56±0.02	7.52±0.02	2.08±0.02	5.84±0.02	18.24±0.03	56.28±0.03

All values mean ± SEM of 5 determinations (replicates)

Table 76. Proximate composition of lentil of the four cultivars affected by inoculation with *Rhizobium* and/or Mycorrhiza and rock phosphate .

Var.	Treatment	Moisture (%)	Ash (%)	Ether Extract (%)	Crude Fibers(%)	Crude Protein (%)	Carbohydrate(%)
NARC-2008-2 V₇	Control	5.72±0.02	1.34±0.02	1.84±0.02	15.3±0.02	22.6±0.11	52.08±0.03
	VAM	7.32±0.02	3.18±0.02	2.46±0.01	24.6±0.11	23.6±0.11	37.82±0.02
	RHZ	7.72±0.03	3.64±0.02	2.12±0.03	11.74±0.04	22.4±0.18	51.26±0.03
	RHZ+VAM	6.06±0.02	2.78±0.03	2.46±0.01	6.72±0.02	26.98±0.03	54.44±0.05
	RP	8.24±0.02	3.84±0.02	2.12±0.02	6.14±0.02	24.78±0.09	54.2±0.02
	MRP₁	6.76±0.01	2.34±0.02	2.24±0.02	12.46±0.01	24.18±0.03	51.56±0.03
	MRP₂	6.19±0.02	1.46±0.01	2.76±0.03	13.74±0.02	24.52±0.03	50.76±0.03
NARC-2008-3 V₈	Control	6.58±0.03	1.72±0.02	2.62±0.02	11.24±0.02	22.8±0.09	54.3±0.03
	VAM	7.36±0.03	1.96±0.01	2.06±0.01	15.42±0.02	23.34±0.02	49.34±0.05
	RHZ	7±0.01	1.22±0.02	2.06±0.01	14.86±0.01	24.8±0.02	49.56±0.05
	RHZ+VAM	6.72±0.02	1.32±0.02	2.6±0.01	11.54±0.02	24.44±0.02	52.52±0.03
	RP	6.36±0.03	1.84±0.02	2.06±0.01	18.7±0.04	24.5±0.02	45.68±0.04
	MRP₁	7.84±0.02	1.44±0.02	2.46±0.01	13.56±0.03	24.86±0.01	49.36±0.04
	MRP₂	7.18±0.03	2.36±0.01	2.02±0.10	12.02±0.02	25.28±0.02	50.96±0.02
NARC-2008-4 V₉	Control	6.24±0.02	1.64±0.02	2.86±0.01	11.94±0.02	24.24±0.02	52.74±0.02
	VAM	6.14±0.02	1.6±0.01	2.64±0.02	15.6±0.03	25.24±0.02	48.46±0.03
	RHZ	6.62±0.02	1.72±0.02	2.86±0.01	20.82±0.04	24.94±0.02	42.56±0.04
	RHZ+VAM	6.48±0.02	3.64±0.02	2.06±0.01	23.72±0.03	25.52±0.02	38.36±0.04
	RP	7.44±0.02	2.04±0.02	2.66±0.01	15.08±0.46	24.74±0.04	46.56±0.04
	MRP₁	9.7±0.03	2.2±0.03	2.36±0.01	17.08±0.03	24.26±0.03	43.7±0.03
	MRP₂	5.9±0.01	3.22±0.02	2.16±0.01	10.48±0.06	23.08±0.04	54.78±0.03
NARC-2002 V₁₀	Control	6.24±0.02	2.83±0.01	2.68±0.01	18.06±0.05	23.86±0.02	45.82±0.03
	VAM	5.86±0.01	1.38±0.02	2.76±0.01	14.66±0.01	25.02±0.03	50.14±0.10
	RHZ	5.9±0.01	2.06±0.01	2.36±0.01	12±0.02	25.18±0.03	52.14±0.06
	RHZ+VAM	4.98±0.02	2.14±0.01	2.46±0.01	15.94±0.02	25.2±0.02	48.7±0.04
	RP	7.98±0.02	2.14±0.01	2.28±0.01	9.82±0.02	24.78±0.09	52.32±0.07
	MRP₁	6.12±0.02	2.34±0.02	2.32±0.03	16.1±0.02	25.14±0.06	47.64±0.04
	MRP₂	8.56±0.03	2.36±0.01	2.64±0.02	16.32±0.03	24.96±0.04	44.72±0.03

All values mean ± SEM of 5 determinations (replicates)

Table 77. LSD value of treatments, varieties and interaction on proximate analyses of all legumes.

Proximate composition	Treatment(A) LSD	Varietal (B) LSD	Interaction (AB)LSD
Ash	0.05971	0.07136	0.1888
Carbohydrate	0.09233	0.1104	0.2920
FAT	0.05427	0.06486	0.1716
Moist content	0.06932	0.08285	0.1888
Fiber Content	0.1381	0.1650	0.4366
Protein content	0.1201	0.1435	0.3797

LSD value at alpha = 0.050

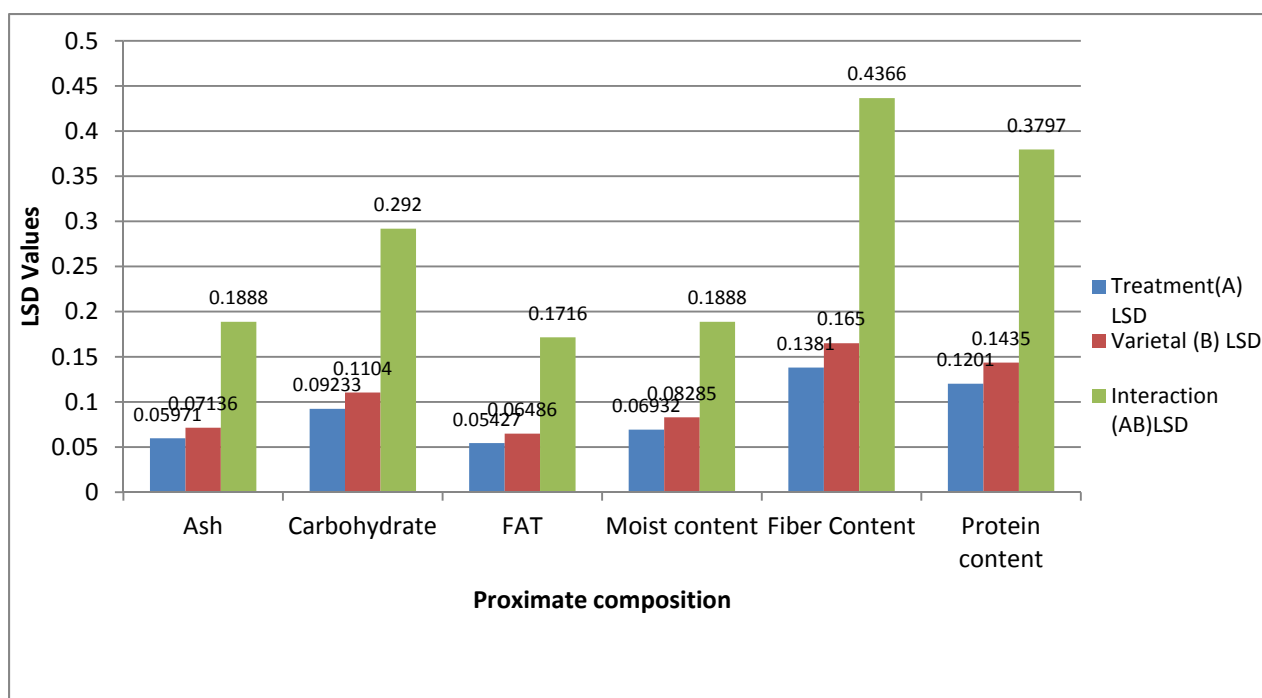
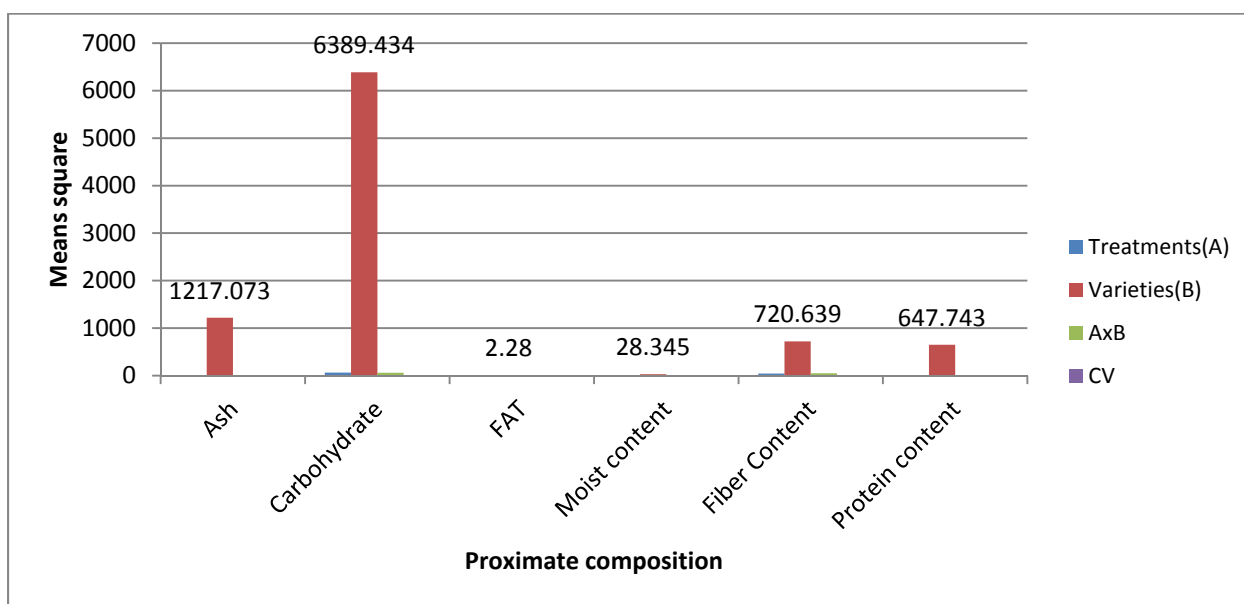


Fig.63. Proximate composition of lentil of the four cultivars affected by inoculation with *Rhizobium* and/or Mycorrhiza and rock phosphate.

Table 78. Means square (3 replicates) of proximate of all studied legumes.

Proximate composition	Treatments(A)	Varieties(B)	AxB	CV
Ash	3.373	1217.073	3.941	2.74%
Carbohydrate	61.226	6389.434	59.992	0.40%
Fat	1.795	2.280	0.810	5.64%
Moist content	6.272	28.345	4.129	2.26%
Fiber Content	43.758	720.639	47.781	3.15%
Protein content	9.407	647.743	5.899	1.38%

**Fig.64. Means square (3 replicates) of proximate of all studied legumes.**

IV. MINERAL COMPOSITION

4.8 Effect of AM, rhizobia , Rockphosphate and their combine interaction on minerals composition

Means result of inoculated plants on nutrient uptake of plants of are given in Tables 79-81 and Fig.68-73. The dual inoculation of AM fungi, *Rhizobium* and rock phosphate *showed* maximum values in all the tested parameter than plants inoculated with individual Tables 79-81 and Fig.68-73. The result showed that dry matter yield of macro and micro nutrients significantly different. The effect of treatments, varieties response and the interaction between treatments and varieties ($P > 0.0053$) or 99.4% ($P > 0.0312$) or 97% 100 % ($P > 0.0000$) respectively significant. The effect of inoculation was found to be more prominent as compared to uninoculated association. Nutrients (Mn, Na, K, Cu, Mg, Fe and Zn etc) uptake of are given in Tables 79-81 and Fig.68-73 showed that varieties and the effect of treatments were significantly different. Maximum uptake of nutrient was attained. The result showed that inoculation treatments led to improved seed nutrient composition to a varying. Omomowo *et al.* (2009) reported that presence of the various mineral nutrients such as Ca, Mg, K, N, Na, Zn, Cu, Fe and Mn are of biochemical importance to the physiology of the seeds. Satter *et al.* (2006) studied the influence of arbuscular mycorrhiza and phosphate rock on uptake of major nutrients by *Acacia mangium* seedlings on degraded soil and found that nutrient use efficiency in the AM-inoculated seedlings was also significantly higher than in uninoculated seedlings.

Macronutrients

Sodium (Na)

The results presented in Tables 79-81 and Fig.68-73 show that there were significant differences between cultivars in Na level in *Vigna radiata* (V_1 - V_3) ranged from $(0.242 \pm 0.5591$ to 0.006 ± 0.0027 mg/100), in *Macroptilium bracteatum* from $(0.002 \pm 0.0039$ to 0.0011 ± 0.0066 mg/100 g), in *Pisum sativum* Na ranged from $(0.003 \pm 0.0014$ to 0.008 ± 0.0009 mg/100 g) ,in *Desmodium adscendens* from $(0.003 \pm 0.0010$ to 0.007 ± 0.0015 mg/100 g) and Na level in *Lens culinaris* (V_7 - V_{10}) ranged from $(0.129 \pm 0.0144$ to 0.886 ± 0.0174 mg/100 g). Results Tables 79-81 and Fig.68-

73 showed that varieties and the effect of treatments were significantly different. The result showed that inoculation treatments led to improved seed nutrient composition to a varying degree, over the uninoculated control. Omomowo *et al.* (2009) reported that presence of the various mineral nutrients such as Ca, Mg, K, N, Na, Zn, Cu, Fe and Mn are of biochemical importance to the physiology of the seeds. Maximum uptake of nutrient was attained at mycorrhizal and rhizobium combined inoculated plants than control. Our result match with John (2002) reported that both the fungal and rhizobial microsymbionts improve mineral nutrition of the host plant and also agree with the statement of Zaidiet *al.* (2003) who reported that nutrient uptake was significantly enhanced as a result of inoculation with *Rhizobium* sp. and phosphate solubilizing microorganisms (PSM). Nutrient uptake was further augmented by the addition of AM fungus, *Glomus fasciculatum* in the combined inoculation treatment with *Rhizobium* sp. Instead of rhizobium and VAM fungi rock phosphate level effect acquisition of nutrients our result in line with Kalipada & Singh (2003) reported that the inoculation of phosphate solubilizing bacteria (PSB) +vesicular arbuscular mycorrhiza (VAM) recorded high nutrient uptake over PSB and VAM individual applications. The nutrient uptake also increased with increasing levels of MRP also reported by Azmatet *al.* (2005) that the effect of (Cadmium) Cd metal on essential mineral ions nutrients of *Vigna radiata* (bean) plants was examined. Results were explained in relation to soil microorganism and acquisition of mineral nutrients like Na, K, Ca, Mg, Mn, PO₄ and Fe. Result also in line with The higher plant height registered by T9 ($\frac{3}{4}$ RR +M++) ,shows the versatility of AMF. Mycorrhiza can increase the uptake of macronutrients other than P including N, K provided by the inorganic fertilizer and Mg (Clark & Zeto, 2000 & Hodge *et al.*, 2001) as well as uptake of micronutrients.

Manganesem (Mg)

The results Tables 79-81 and Fig.68-73 elncidate that there were significant differences between cultivars in Mg level in *Vigna radiata* (V₁-V₃) ranged from (2.167±0.0060 to 3.803±0.0055 mg/100 g), in *Macroptilium bracteatum*, (1.868±0.0050 to 3.134±0.0067 mg/100 g), in *Pisum sativum* from 0.835±0.0027to 2.046±0.0065 mg/100 g, in *Desmodium adscendens* ranged from (1.110±0.0026 to 2.800±0.00 20 mg/100 g) and in *Lens culinaris* varieties (V₇-V₁₀) ranged from (1.300±0.0058 to

3.698±0.0082). Result showed that varieties and the effect of treatments were significantly different. Maximum uptake of nutrient was attained at inoculated plants than control. our result agree with John (2002) reported that both the fungal and rhizobial micro symbionts improve mineral nutrition of the host plant and also match with the result of vesicular arbuscular mycorrhizal fungi (VAMF) is a soil-based biofertilizer which functions for better absorption of nutrients and water. This may be attributed to the ability of the VAM fungi to form an extramatrical hyphae in the roots to better absorbed water, solubilized phosphates and other nutrients needed for the intermediate and later growth stages of plant (Gosling *et al.*, 2006; Rotor & Delima 2010; Habte & Osorio (2002) who investigated that AM fungi absorb P, K, Ca, Mg, Fe, Mn, Cu, and Zn from the soil and then translocation these nutrient to the plants. VAM.RHZ, VAM+RHZ, RP and RP+VAM enhanced uptake of Mg in all varieties but more in broad leaves legumes (*Desmodium adscendens*, *Macroptilum bracteatum* and *Vigna radiata* than *Lens culinaris*). The results are in good agreement with that of Belesky *et al.* (2001) and Khan *et al.* (2006a), who find out that mineral ion concentration in broadleaf plants including leguminous plants are more than those in grasses and other forages. Our results are supported by the following workers (Waidyanatha *et al.*, 1979; Lukiwati *et al.*, 1997a; Lukiwati *et al.*, 1997b; Jagviret *et al.*, 2004), who reported that nutrient uptake of mycorrhizal plants was higher compared to non-mycorrhizal Mycorrhiza alone or in combination with rhizobium or rock phosphate enhanced the uptake of Mg our result supported by the following workers (Liu *et al.*, 2002, Jagviret *et al.*, 2004; Neveen *et al.*, 2008; Murthy, 2011).

Potassium (K)

The results Tables 79-81 and Fig.68-73 indicated that there were significant differences between cultivars in Mg level in *Vigna radiata* (V₁-V₃) ranged from 4.749±0.0508 to 13.75±3.656 mg/100 g, in *Macroptilum bracteatum*, from 5.066±0.0093 to 6.890±0.0431 mg/100 g, *Pisum sativum* from 3.265±0.0341 to 13.07±2.645 mg/100 g, in *Desmodium adscendens* ranged from 2.365±0.0173 to 6.426±0.0260 mg/100 g and in *Lens culinaris* varieties ranged from 5.837±0.0282 to 11.13±5.590. There were visible difference in the seed Cu in all *Vigna radiata* L., *Macroptilum bracteatum*, *Pisum sativum*, *Desmodium adscendens* and *Lens culinaris* cultivars. Our results agree with

Muhammad (2003), who also reported that potassium content varied from 789.69-809.22 mg/100gm of seed among the different cultivars of *Lens culinaris*.

Results showed that varieties are significant but the effect of *Rhizobium* and rock phosphate treatments were not significantly different. Maximum uptake of nutrient was attained at mycorrhizal inoculated plants than other. Our result agree with Bressan *et al.* (2001) reported that the AM- fungi also increases the uptake of K, and concentration of K has been found more in mycorrhizal than non-mycorrhizal plants and also in line with Habte & Osorio (2002), who stated that AM fungi absorb P, K, Ca, S, Fe, Mn, Cu, and Zn from the soil and then translocate these nutrient to the plants. *Rhizobium* + VAM mycorrhizal fungi and rock phosphate + VAM mycorrhizal fungi in combine form enhanced uptake of K. Neveen *et al.* (2008) also reported that fungal infection and rhizobial inoculation either alone or in combination in mungbean with 50% or 75% of the recommended doses of N and/or P fertilizers increased plant growth and yield as well as the concentration of N, P, K, Fe, Zn, Mn, Cu. Khan *et al.* (2008) also reported that nitrogen, phosphorus and potassium uptake % was also more due to dual inoculations and similarly Bhat *et al.* (2011) investigated that seed inoculation with *Rhizobium* significantly increased total nitrogen (89.17 kg ha⁻¹), phosphorus (9.15 kg ha⁻¹) and potassium uptake (55.6 kg ha⁻¹) by green gram. *Rhizobium* also enhanced the uptake of K, but not more than when in combine form. Similar report presented by Bhat *et al.* (2010) that seed inoculation with *Rhizobium* the maximum phosphorous and potassium content in grain and straw recorded was 0.465 and 0.246 percent and 0.881 and 2.274 percent respectively. It might be due to increased nitrogen fixation with *Rhizobium* inoculation resulting in more builds up of nitrogen in grain and straw which in turn increased phosphorous and potassium content in the grain.

Micronutrients

Zinc (Zn)

The results presented in Tables 79-81 and Fig.68-73 clarify that there were significant differences between cultivars in Mg level in *Vigna radiate* (V₁-V₃) ranged from 0.084±0.0009 to 0.653±0.0053 mg/100 g, in *Macroptilium bracteatum* from 0.054±0.0006 to 0.278±0.0019 mg/100 g, in *Pisum sativum* from 0.116±0.0245 to

0.243±0.00009 mg/100 g, in *Desmodium adscendens* ranged from 0.049±0.0014 to 0.229±0.0009 mg/100 g and in *Lens culinaris* varieties and species ranged from 0.126±0.0013 to 0.275±0.0015. Results showed Tables 79-81 that varieties are significant but the effect of rhizobium and rock phosphate treatments were not significantly different. Maximum uptake of nutrient was attained at mycorrhizal inoculated plants than other. and the Tufenkci *et al.* (2005) reported that AMF inoculation significantly increases the contents of P, K, Ca and Zn. Murthy (2011) also stated that mature seed samples were rich in sodium, phosphorus, calcium, zinc, manganese and iron and this supported the present results. , AMF have been shown to improve immobile nutrients uptake such as P, Zn, Ca and Cu (Liu *et al.*, 2002; Jamal & Naser, 2002; Habte & Osorio, 2002; Chen *et al.*, 2003). George (2000) observed that the colonization of plant roots by arbuscular mycorrhiza (AM) fungi can greatly affect the plant uptake of mineral nutrients. Many mycorrhizal fungi can transport nitrogen, phosphorus, zinc, and copper to the host plant. Rohyadi *et al.* (2004) investigated that there were differential effects of the two fungi on uptake of mineral elements. Plants inoculated with *Gigaspora margarita* took up a range of elements, including P and Zn as well as Al, to a much greater extent than those inoculated with *Glomus etunicatum*, regardless of medium Ph rhizobium inoculation alone less effect on Zn uptake than those inoculated with both rhizobium and mycorrhizal our result agree with Neveen *et al.* (2008), who reported that fungal infection and rhizobial inoculation either alone or in combination with 50% or 75% of the recommended doses of N and/or P fertilizers increased nodules formation, plant growth and yield as well as the concentration of N, P, K, Fe, Zn, Mn, Cu, protein and total carbohydrate on both cultivars as compared to uninoculated plants. Singh & Singh (2010) stated that the sulfur (S) and cobalt (Co) application of fertilizer at recommended dose significantly enhanced micronutrient uptake as compared to application of *Rhizobium* inoculants. The maximum nutrient contents of Fe 318.33, 357.33 ppm; Zn 36.00, 56.33 ppm; Mn 98.0, 108.0 ppm; and Cu 25.33, 18.0 ppm in grain. Subba Roa (2001a) reported that mycorrhiza have been widely accepted as bio-fertilizers, However these supply only major nutrients but a host of microorganism that can transform micronutrients are there in soil that can be used as bio-fertilizers to supply micronutrients like zinc, iron, copper etc. Habte & Osorio (2002)

observed that AM fungi absorb P, K, Ca, S, Fe, Mn, Cu, and Zn from the soil and then translocate these nutrients to the plants. The present findings also agree with Sheraz *et al.* (2010), who reported that AM-fungi also increases the uptake and efficiency of micronutrients like Zn, Cu, Fe etc. by secreting the enzymes, organic acids which makes fixed macro and micronutrients mobile and as such are available for the plant.

Iron (Fe)

Tables 1d-3d show that there were significant differences between cultivars in Mg level in *Vigna radiata* (V₁-V₃) ranged from 0.160±0.0305 to 3.043±0.0173 mg/100 g, in *Macroptilium bracteatum* from 0.141±0.0011 to 2.377±0.0053 mg/100 g, in *Pisum sativum* from 0.175±0.0183 to 1.828±0.0079 mg/100 g, in *Desmodium adscendens* ranged from 0.675±0.0116 to 1.397±0.0245 mg/100 g and among *Lens culinaris* varieties (V₇-V₁₀) it ranged from 0.0200±0.0112 to 2.441±0.0240.

Results showed in Tables 79-8, that varieties are significant but the effect of rhizobium and rock phosphate treatments were not significantly different. Maximum uptake of nutrient was attained at mycorrhizal inoculated plants. The results agree with those of Sheraz *et al.* (2010), who reported that AM-fungi also increases the uptake and efficiency of micronutrients like Zn, Cu, Fe etc. by secreting the enzymes, organic acids which makes fixed macro and micronutrients mobile and as such are available for the plant. Habte & Osorio (2002) stated that AM fungi absorb P, K, Ca, S, Fe, Mn, Cu, and Zn from the soil and then translocate these nutrients to the plants. VAM+RHZ, VAM+RP inoculated plants also increased the uptake of Fe Tables 79-81. The present result agrees with Neveen *et al.* (2008), who reported that fungal infection and rhizobial inoculation either alone or in combination with 50% or 75% of the recommended doses of N and/or P fertilizers increased plant growth and yield as well as the concentration of N, P, K, Fe, Zn, Mn in mungbean. Rock phosphates alone decrease the uptake of Fe. Singh & Singh (2010) reported that the sulfur (S) and cobalt (Co) application of fertilizer at recommended dose significantly enhanced micronutrient uptake as compared to application of *Rhizobium* inoculant. The maximum nutrient content of Fe 318.34, 355.33 ppm; Zn 36.00, 56.32 ppm; Mn 98.0, 108.0 ppm; and Cu 25.33, 18.0 ppm in grain. Subba Roa (2001a) reported that mycorrhiza have been widely accepted as bio-fertilizers, However these supply only major nutrients but a host of microorganism that can transform

micronutrients are there in soil that can be used as bio-fertilizers to supply micronutrients like zinc, iron, copper etc. Murthy (2011) reported that mature seed were rich in sodium, phosphorus, calcium, zinc, manganese and iron.

Copper (Cu)

There were significant differences between shown in Tables 79-81 that cultivars in Mg level in *Vigna radiata* (V₁-V₃) 0.129 ± 0.0027 to 0.298 ± 0.0056 mg/100 g, in *Macroptilum bracteatum* from 0.103 ± 0.0030 to 0.282 ± 0.0019 mg/100 g, in *Pisum sativum* from 0.284 ± 0.0006 to 0.570 ± 0.0039 mg/100 g, in *Desmodium adscendens* ranged from 0.105 ± 0.0006 to 0.549 ± 0.0053 mg/100 g among *Lens culinaris* varieties (V₇-V₁₀) ranged from 0.047 ± 0.0008 to 0.671 ± 0.0031 . Result showed that varieties are significant but the effect of rhizobium and rock phosphate treatments were not significantly different. Maximum uptake of nutrient was attained at mycorrhizal inoculated plants. The results of Neveen *et al.* (2008) also supported the present finding that fungal infection and rhizobial inoculation either alone or in combination with 50% or 75% of the recommended doses of N and/or P fertilizers increased the concentration of N, P, K, Fe, Zn, Mn, Cu, in mungbean as compared to uninoculated plants. Similarly, Mathur & Vyas (2000) stated that mycorrhizal fungi may increase the uptake of many other nutrients such as N, S, Ca, Zn, and Cu in faba bean.

Singh & Singh (2010) reported that application of fertilizer significantly enhanced micronutrient uptake as compared to application of *Rhizobium* inoculants. Sheraz *et al.* (2010) reported that AM-fungi also increases the uptake and efficiency of micronutrients like Zn, Cu, Fe etc. by secreting the enzymes, organic acids which makes fixed macro and micronutrients mobile and as such are available for the plant. George (2000) observed that the colonization of plant roots by arbuscular mycorrhiza (AM) fungi can greatly affect the plant uptake of mineral nutrients. Many mycorrhizal fungi can transport zinc, Mg, Na, K, Fe and Cu to the host plant Fig.(68-73). Our results agree with Mathur & Vyas (2000) that mycorrhizal fungi may increase the uptake of many other nutrients such as N, S, Ca, Zn, and Cu. Subba Roa (2001a) have similar results that mycorrhiza have been widely accepted as bio-fertilizers, However these supply only major nutrients but a host of microorganism that can transform micronutrients are there in soil that can be used as bio-fertilizers to supply micronutrients like zinc, iron, copper etc.

Manganese (Mn)

Manganese is essential for development of chloroplast. Its deficiency leads to the discoloration of leaves and other parts of the plant. The results (Tables 79-81) that significant differences between cultivars in Mn level in *Vigna radiata* (V₁-V₃) 1.425±0.113 to 2.188±0.102 mg/100 g, in *Macroptilum bracteatum* from 0.643±0.0118 to 1.417±0.0062 mg/100 g, in *Pisum sativum* from 0.476±0.066 to 0.685±0.0190 mg/100 g, in *Desmodium adscendens* ranged from 0.517±0.0198 to 1.752±0.0043 mg/100 g among *Lens culinaris* varieties (V₇-V₁₀) ranged from 0.549±0.0053 to 0.671±0.0031 result showed that varieties are significant but the effect of rock phosphate alone treatment was significantly different. Omomowo *et al.* (2009) reported that inoculation treatments with *Glomus mosseae* and / or *Bradyrhizobium japonicum* led to both direct and residual significant benefits on the seed proximate and seed nutrient element composition of cowpea. Maximum uptake of nutrient was attained at mycorrhizal inoculated plants Fig. (68-73). Our results agree with the Mathur & Vyas (2000) in this sense that mycorrhizal fungi increase the uptake of many other nutrients such as Na, Mn, Ca, Zn, and Cu. Our results are in line with the findings of other workers (Habte & Osori, 2002; Azmat *et al.*, 2005; Neveen *et al.*, 2008; Singh & Singh, 2010; Murthy, 2011). Rock phosphate alone decreased all minerals uptake and agree with the stimulation of faba bean symbiotic activity and seed yield by mycorrhizal inoculation was suppressed by the application of rock phosphorus (Ahmed *et al.*, 2000). There are chemical variation, varietal and even same treatment variation among winter (lentil and pea) and summer legumes (Green mung bean, desmodium and burgundy). The same results were observed by Karadavut & Palta (2010) who explained that chemical composition varied in different locations. Stacey *et al.* (2006) explained that chemical composition varied with time.

Table 79. Mineral composition of *Vigna radiata* (V₁-V₃), *Macroptilum bracteatum* affected by inoculation with *Rhizobium* and/or Mycorrhiza and rock phosphate.

Varieties/specie	Treatment	Mg (ppm)	Na (ppm)	K (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)
Niab-92 V₁*	Control	2.811 0.0148	0.242±0.5591	0.033±0.0029	0.155±0.0190	0.897±0.0062	0.160±0.0305	0.103±0.0017
	VAM	2.863±0.0096	0.580±0.0027	6.872±0.968	0.178±0.0012	1.425±0.113	0.204±0.0077	0.152±0.0009
	RHZ	2.249±0.0029	0.003±0.0033	4.749±0.0508	0.238±0.0017	1.368±0.0090	0.222±0.0194	0.123±0.0004
	RHZ+VAM	5.713±0.0523	0.001±0.0021	7.124±0.0447	0.206±0.0007	1.508±0.0065	0.368±0.0139	0.102±0.0016
	RP1	2.167±0.0060	0.0000±0.0019	5.935±0.0280	0.180±0.0011	0.887±0.9860	0.199±0.0172	0.084±0.0007
	MRP1	3.240±0.0089	0.000±0.0031	8.477±0.0777	0.213±0.0018	0.986±0.0098	0.211±0.0132	0.112±0.0004
	MRP2	3.583±0.0116	0.000±0.0014	11.39±4.815	0.171±0.0010	0.980±0.0061	0.234±0.0179	0.134±0.0007
Niab-98 V₂**	Control	3.205±0.0140	0.001±0.0007	10.58±0.211	0.175±0.0007	0.797±0.0098	0.167±0.0290	0.084±0.0009
	VAM	2.702±0.0044	0.001±0.0007	19.78±0.073	0.239±0.0013	1.689±0.0060	0.395±0.0057	0.112±0.0003
	RHZ	3.308±0.0101	0.003±0.0023	10.92±0.078	0.324±0.0031	1.937±0.0067	0.280±0.0210	0.098±0.0004
	RHZ+VAM	3.450±0.0030	0.005±0.0024	13.75±3.656	0.132±0.0013	1.166±0.0006	0.382±0.0262	0.50±0.0013
	RP1	2.251±0.0027	0.002±0.0009	6.806±0.0397	0.129±0.0027	0.903±0.0027	0.357±0.0187	0.101±0.0016
	MRP1	3.054±0.0063	0.003±0.0025	7.400±0.0247	0.175±0.0007	0.616±0.0086	0.357±0.0068	0.066±0.0002
	MRP2	3.803±0.0055	0.004±0.0005	9.243±0.0256	0.210±0.0016	1.677±0.0048	0.364±0.0135	0.96±0.0006
Niab-2006V₃***	Control	2.724±0.0073	0.001±0.0014	10.70±0.021	0.201±0.0006	1.308±0.0144	0.218±0.0231	0.088±0.0018
	VAM	3.803±0.0055	0.003±0.0026	16.94±0.475	0.298±0.0056	2.188±0.102	1.679±0.0036	0.230±0.0010
	RHZ	2.721±0.0155	0.002±0.0011	11.12±0.021	0.199±0.0003	1.533±0.117	1.003±0.0227	0.142±0.0008
	RHZ+VAM	4.026±0.0072	0.006±0.0027	14.52±2.617	0.233±0.0113	2.477±0.0042	3.043±0.0173	0.653±0.0053
	RP1	2.561±0.0111	0.005±0.0021	10.91±0.034	0.154±0.1342	1.165±0.0048	0.146±0.0224	0.107±0.0011
	MRP1	2.865±0.0067	0.003±0.0033	10.60±0.074	0.211±0.1110	1.417±0.0062	0.231±0.0093	0.120±0.0015
	MRP2	2.988±0.0091	0.005±0.0020	11.26±0.114	0.188±0.1010	1.765±0.0043	0.370±0.0105	0.137±0.0015
<i>Macroptilum bracteatum</i>	Control	2.426±0.0056	0.002±0.0039	5.066±0.0093	0.141±0.0011	0.643±0.0118	0.138±0.0158	0.151±0.0019
	VAM	3.134±0.0067	0.005±0.0019	5.389±0.0860	0.209±0.0010	1.835±0.0053	2.377±0.0053	0.088±0.0007
	RHZ	2.632±0.0080	0.003±0.0031	6.452±0.0530	0.182±0.0011	1.137±0.0097	1.644±0.0103	0.278±0.0019
	RHZ+VAM	2.149±0.0102	0.007±0.0059	6.643±0.0690	0.282±0.0019	1.417±0.0062	1.644±0.0076	0.227±0.0028
	RP1	1.868±0.0050	0.004±0.0061	3.455±0.0153	0.096±0.0030	0.805±0.0068	0.675±0.0116	0.150±0.0006
	MRP1	2.569±0.0073	0.006±0.0075	5.901±0.0176	0.103±0.0030	0.423±0.0067	0.705±0.0041	0.121±0.0009
	MRP2	2.848±0.0062	0.0011±0.006	6.890±0.0431	0.105±0.0020	0.766±0.0072	0.844±0.0067	0.054±0.0013

All values mean ± SEM of 5 determinations (replicates)

Table 80. Mineral composition of *Pisum sativum* and *Desmodium adscenden* affected by inoculation with *Rhizobium* and/or Mycorrhiza and Rock phosphate.

Species	Treatment	Mg (ppm)	Na (ppm)	K (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	Zn (ppm)
	Control	0.835±0.0027	0.003±0.0014	3.265±0.0341	0.476±0.066	0.321±0.0090	0.175±0.0183	0.116±0.0245
	VAM	2.046±0.0065	0.006±0.0024	13.07±2.645	1.038±0.0063	0.521±0.0057	0.452±0.0084	0.187±0.0013
	RHZ	1.73±0.0032	0.007±0.0015	7.176±0.839	0.557±0.0091	0.551±0.0129	0.488±0.0151	0.199±0.0018
	RHZ+VAM	1.139±0.0056	0.105±0.0178	9.092±0.0916	0.550±0.0173	0.332±0.0426	1.828±0.0079	0.243±0.00009
	RP1	1.129±0.0057	0.002±0.0021	9.175±0.0229	0.685±0.0190	0.284±0.0006	0.256±0.0074	0.178±0.0076
	MRP1	1.451±0.0026	0.006±0.0028	11.61±3.737	0.610±0.0137	0.397±0.0054	0.448±0.0322	0.211±0.0043
	MRP2	1.471±0.0065	0.008±0.0009	12.84±2.766	0.680±0.0009	0.570±0.0039	0.515±0.0126	0.233±0.0007
	Control	1.110±0.0026	0.003±0.0010	2.365±0.0173	0.805±0.0077	0.096±0.0030	0.675±0.0116	0.104±0.0006
	VAM	2.569±0.0073	0.013±0.0076	6.913±0.0116	1.739±0.0023	0.132±0.0030	1.871±0.0277	0.199±0.0002
	RHZ	2.848±0.0062	0.004±0.0018	6.426±0.0260	0.517±0.0198	0.282±0.0019	1.098±0.0043	0.229±0.0009
	RHZ+VAM	2.945±0.0088	0.105±0.01678	6.208±0.0498	1.752±0.0043	0.105±0.0006	1.397±0.0245	0.133±0.0016
	RP1	1.568±0.0013	0.006±0.0024	4.970±0.0386	0.892±0.0009	0.112±0.0035	0.921±0.0068	0.049±0.0014
	MRP1	2.046±0.0065	0.003±0.0014	5.123±0.0065	0.971±0.0291	0.123±0.0020	0.618±0.0145	0.122±0.0013
	MRP2	2.800±0.0020	0.007±0.0015	5.981±0.0178	0.988±0.0081	0.549±0.0053	0.607±0.0263	0.131±0.0231

All values mean ± SEM of 5 determinations (replicates)

Table 81. Mineral composition of *Lens culinaris* varieties affected by inoculation with *Rhizobium* and/or Mycorrhiza and Rock phosphate.

Var.	Treatment	Mg (ppm)	Na (ppm)	K (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)
NARC-2008-2 V₇ **	Control	2.191±0.0114	0.495±0.0045	7.477±0.1224	0.906±0.0014	0.156±0.0014	1.0646±0.0116	0.117±0.0009
	VAM	2.586±0.0093	0.783±0.0155	10.10±5.771	0.389±0.0019	0.278±0.0021	0.0200±0.0112	0.224±0.0013
	RHZ	2.946±0.0163	0.645±0.027	11.13±5.590	1.569±0.0090	0.170±0.0028	0.343±0.0115	0.148±0.0020
	RHZ+VAM	3.153±0.0195	0.886±0.0174	10.11±5.816	0.747±0.0057	0.206±0.0015	0.261±0.0116	0.230±0.0019
	RP1	2.080±0.0089	0.292±0.2356	6.918±0.1186	0.570±0.0050	0.144±0.0015	1.452±0.0092	0.101±0.0012
	MRP1	2.488±0.0243	0.405±0.0066	6.506±0.1019	0.787±0.0071	0.156±0.0006	0.852±0.091	0.098±0.0017
	MRP2	2.778±0.0047	0.573±0.046	7.123±0.0268	0.919±0.0101	0.172±0.0024	0.737±0.0260	0.106±0.0011
NARC-2008-3 V₈*	Control	1.300±0.0058	0.459±0.0050	7.351±0.0317	0.860±0.0033	0.047±0.0008	0.783±0.0078	0.128±0.0018
	VAM	2.235±0.0040	0.569±0.0053	9.809±5.3614	0.697±0.0045	0.138±0.0016	0.245±0.0081	0.186±0.0009
	RHZ	2.583±0.0073	0.351±0.0026	7.475±0.1986	0.652±0.100	0.098±0.0033	0.466±0.011	0.115±0.0010
	RHZ+VAM	2.974±0.0137	0.300±0.0426	7.4996±0.018	1.285±0.0063	0.098±0.0015	1.098±0.0043	0.103±0.0023
	RP1	2.787±0.0064	0.286±0.0026	7.047±0.0062	0.965±0.0063	0.106±0.0008	0.457±0.0061	0.175±0.0025
	MRP1	2.893±0.0075	0.357±0.0054	6.726±0.0726	0.988±0.003	0.106±0.0014	0.350±0.0143	0.150±0.0004
	MRP2	3.141±0.0110	0.530±0.0039	8.749±1929	1.047±0.0072	0.161±0.0029	0.585±0.0.198	0.151±0.0010
NARC-2008-4 V₉***	Control	2.141±0.0056	0.577±0.0069	4.073±0.0177	0.982±0.0057	0.173±0.0019	0.610±0.0187	0.134±0.0007
	VAM	2.488±0.0076	0.397±0.0167	6.185±0.0655	2.827±0.103	0.671±0.0031	4.148±0.0482	0.253±0.0009
	RHZ	2.954±0.0141	0.645±0.0027	6.639±0.0799	0.762±0.0079	0.180±0.0020	0.607±0.0263	0.088±0.0011
	RHZ+VAM	3.068±0.0097	0.756±0.0029	9.497±5.3583	0.208±0.0061	0.034±0.0007	1.475±0.0099	0.153±0.0016
	RP1	2.446±0.0084	0.129±0.0144	6.458±0.0338	0.761±0.0041	0.139±0.0029	0.296±0.0234	0.038±0.0010
	MRP1	2.141±0.023	0.292±0.2356	7.470±0.0590	0.770±0.0072	0.239±0.0013	0.342±0.0136	0.127±0.0005
	MRP2	2.459±0.0101	0.573±0.0046	10.11±5.928	0.984±0.0081	0.333±0.0022	0.866±0.0127	0.197±0.0011
NARC- 2002**** V₁₀	Control	2.337±0.0035	0.567±0.0071	6.891±0.3237	0.937±0.0097	0.150±0.0008	1.0646±0.0116	0.197±0.0011
	VAM	2.898±0.0117	0.678±0.0029	8.337 ±0.095	1.156±0.0056	0.203±0.0011	1.450±0.036	0.206±0.0001
	RHZ	3.055±0.0157	0.719±0.0037	6.891±0.3237	1.441±0.115	0.303±0.0020	1.593±0.0335	0.159±0.0010
	RHZ+VAM	3.698±0.0082	0.764±0.0224	10.11±5.928	1.613±0.0046	0.206±0.0011	2.441±0.0240	0.275±0.0015
	RP1	2.538±0.0015	0.477±0.0014	5.837±0.0282	0.559±0.0049	0.159±0.0017	1.901±0.0293	0.126±0.0013
	MRP1	3.121±0.0170	0.627±0.0058	8.484±0.0777	1.184±0.0011	0.220±0.0019	1.388±0.0306	0.172±0.0008
	MRP2	3.172±0.0168	0.682±0.0033	9.496±0.1695	1.920±0.0040	0.333±0.0024	1.587±0.0335	0.176±0.0005

All values mean ± SEM of 5 determinations (replicates)

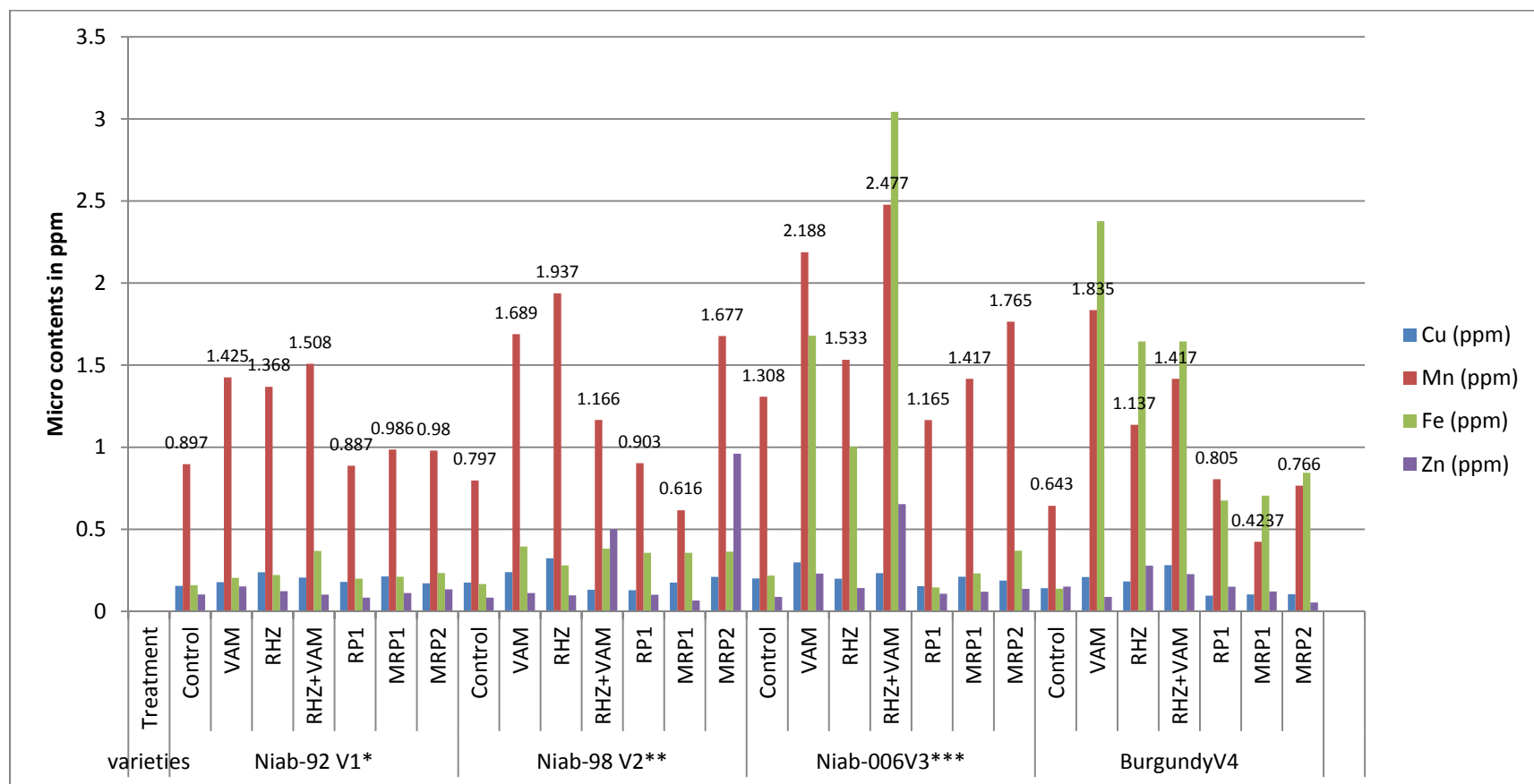


Fig. 65. Micro contents in (V₁-V₃) and *Macroptilum bracteatum* influenced by VAM.RHZ.RP alone and in combined form.

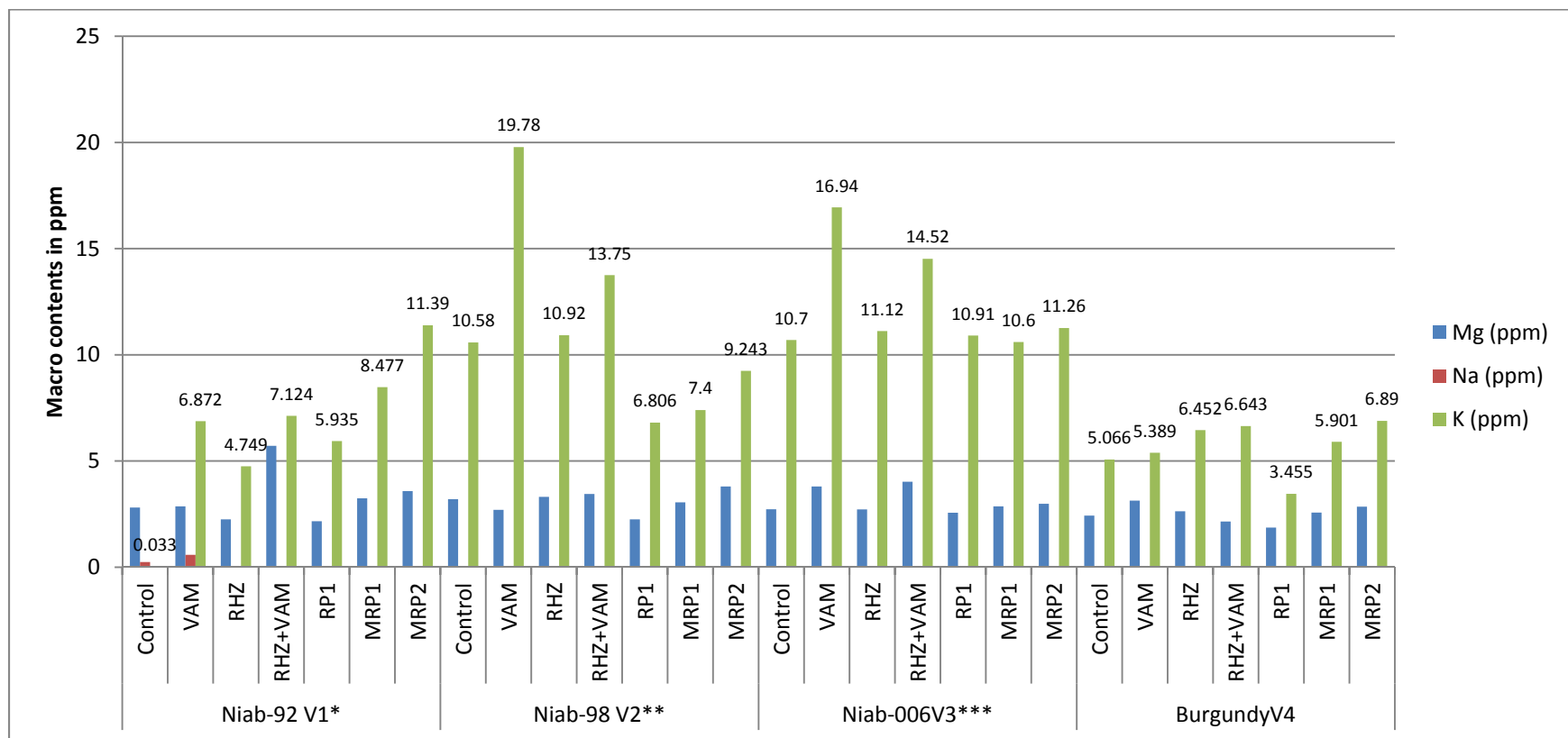


Fig.66. Macro contents in (V₁-V₃) and *Macroptilum bracteatum* influenced by VAM.RHZ.RP alone and in combined form.

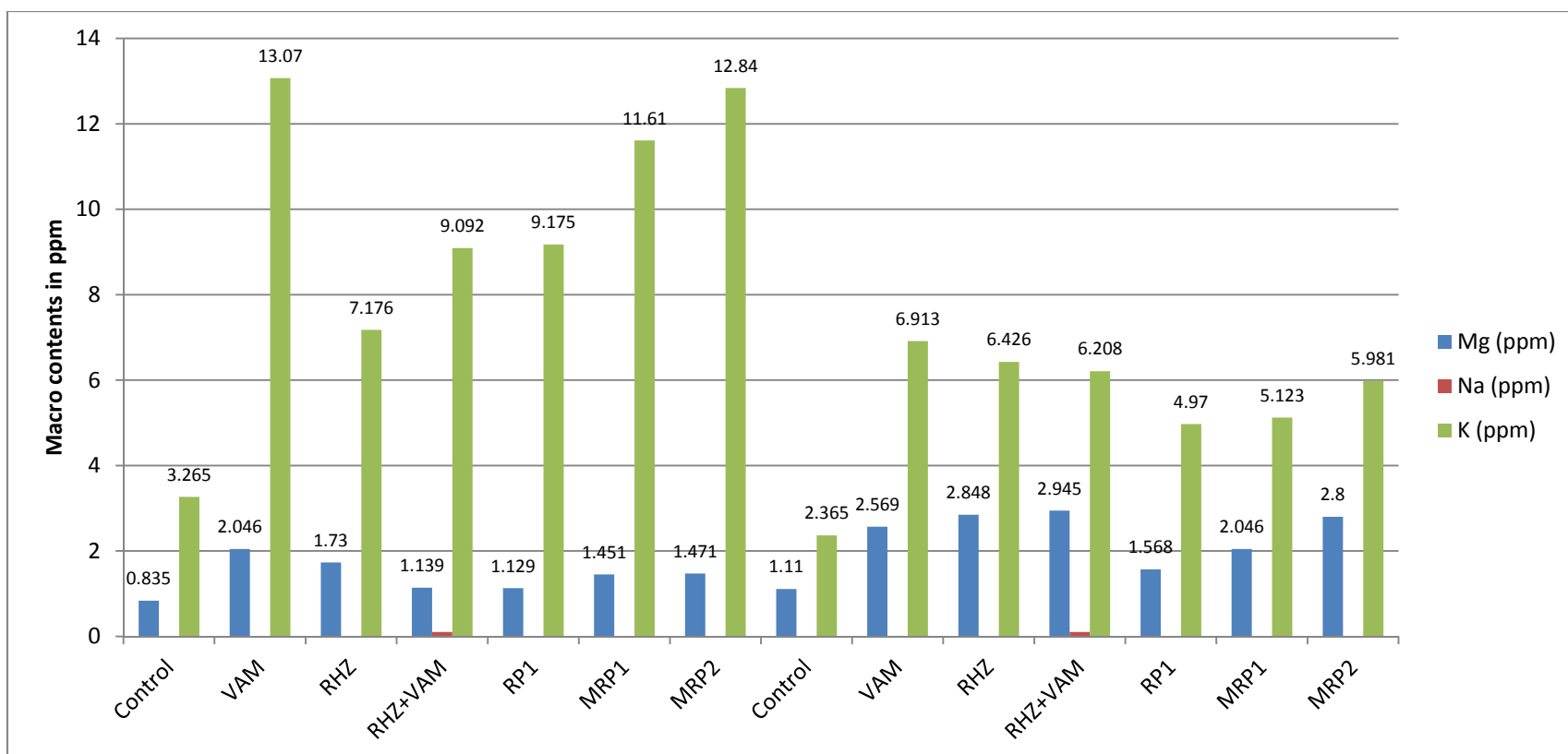


Fig.67. Macro contents in *Pisum sativum* and *Desmodium adscenden* influenced by VAM.RHZ.RP alone and in combined form.

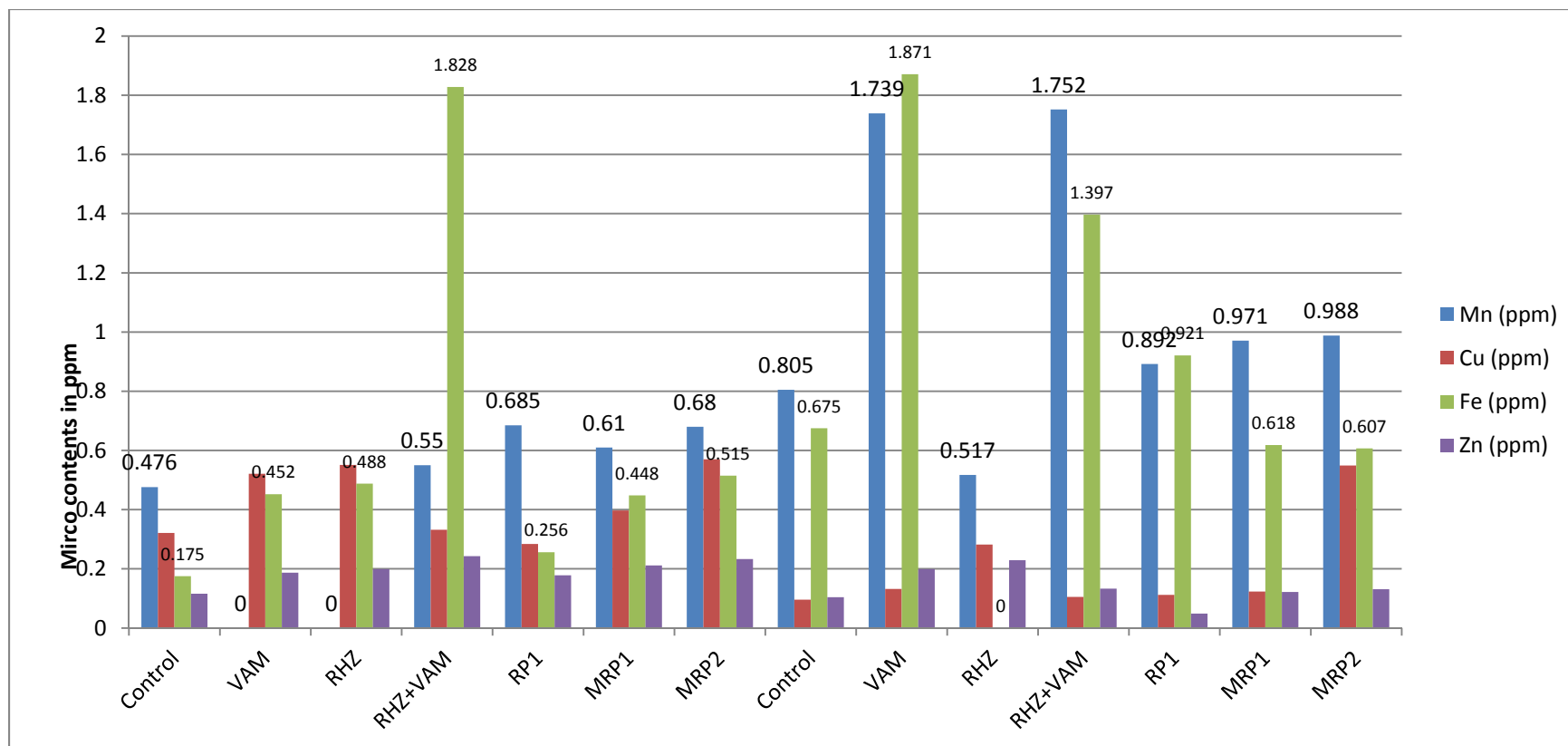


Fig.68. Micro contents in *Pisum sativum* and *Desmodium adscenden* influenced by VAM.RHZ.RP alone and in combined form.

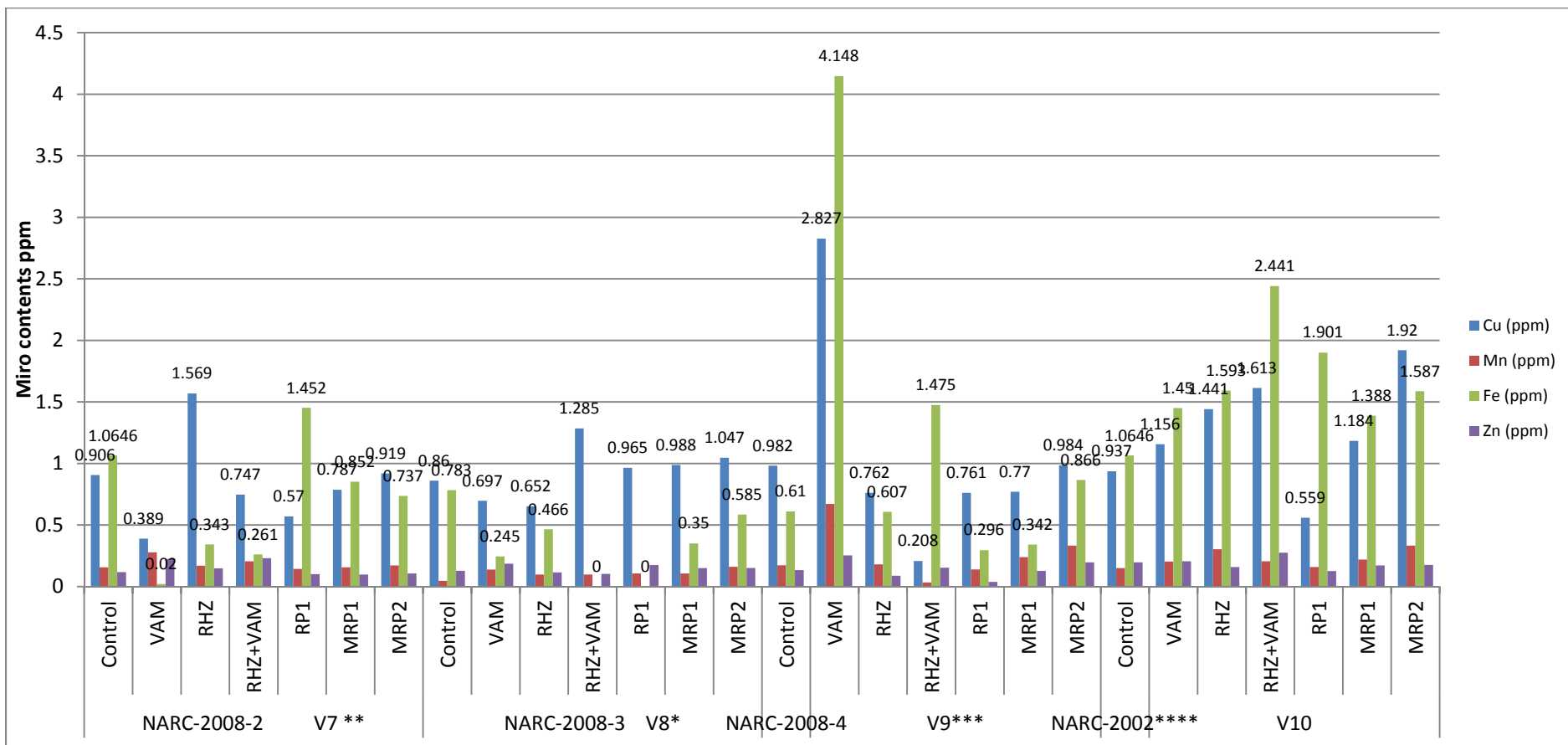


Fig.69. Micro contents in (V₇-V₁₀) influenced by VAM.RHZ.RP alone and in combined form.

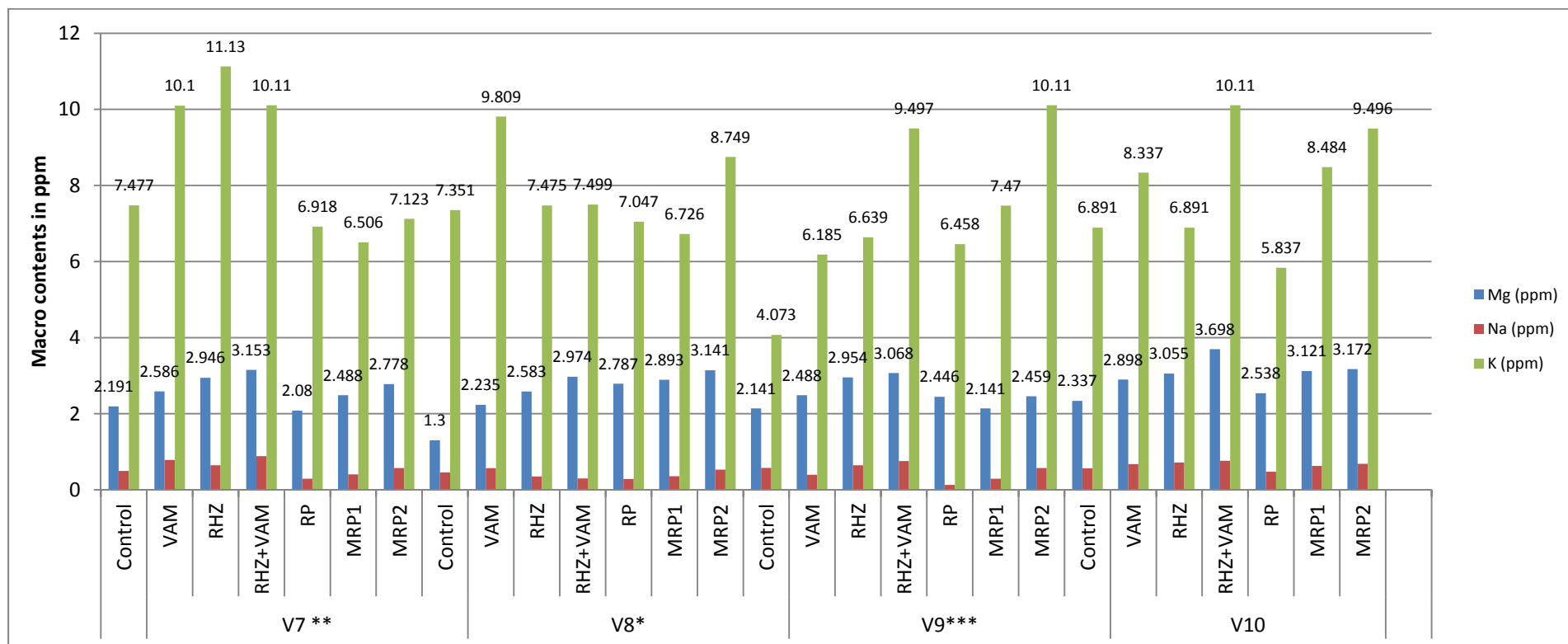


Fig.70. Macro contents in (V₇-V₁₀) influenced by VAM.RHZ.RP alone and in combined form.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. The present experiments strongly suggest that AM-*Rhizobium* combination can significantly reduce use of chemical fertilizers in pulse crops.
2. There is significant efficiency of VAM fungi to enhanced growth, nutrient uptake, productivity, proximate, root colonization and spores density in all studied legumes and more when association with an efficient rhizobium strain. such differences occurred in the the absence of phosphorus deficiency.
3. Therresults indicate that tripartite symiotic association (AMF-*Rhizobium*-Pulses) increased plant productivity. The interactions between AM fungi and bacteria in soil are of significant importance.
4. Inoculation with *Rhizobium*, VAM and rock phosphate led to both direct and significant benefits on the seed proximate and seed nutrient element composition of studied plants.
5. It is recommended that to achieve improved productivity; there is the need to do suitable strain selection of the *Rhizobium*, AM fungi and legume combination to obtain inoculants that are compatible and highly competitive.
6. The findings of this study showed that the breeders should choose the indices on the chemical composition. Dry matter accumulation, moisture and crude protein are suggested as useful indicators for pulse cultivars.
7. It is also concluded that mycorrhizal development pattern in various legumes/pulses variety is genotypic dependent and also growth stages in studied legumes are more related with mycorrhizal colonization at fruiting stages as compared to flowering and vegetative stages.
8. it can be concluded that the use of biofertilizers *Rhizobium* and VAM, with chemical fertilizers is the best RP application @ 15g (kg ha⁻¹), 30 g kg ha⁻¹), and 60 g (kg ha⁻¹) with VAM prove better to single inoculation of RP alone.

9. In conclusion the results of this study indicate that the dual inoculation with VAM fungus and *Rhizobium* is beneficial for better growth and development with increased P uptake.
10. Rock Phosphate application along with VAM, inoculation increased the growth parameters, yield, dry weight of plants, grains, roots colonization significantly.
11. Significant variations were observed in growth parameters from that of the control during the early stages of growth in all the treatments. It was observed that inoculated seeds after germination gave higher biological yield compared to non-inoculated seeds cultivars.
12. Inoculation with high effective strain of *rhizobium* and VAM *spp.* in combination provided good yield and yield attributes.
13. In case of pulses inoculation of soil and seed with *Rhizobium* significantly influenced seed protein content, N-content of shoots and roots and soil, which consequently led to improved soil fertility and can reduce the production cost of next crop through reduced input in the form of nitrogen fertilizers, which in turn also minimize the health hazard effects.
14. Rhizobial inoculation was found to be more effective and produced better yield through positive effect on yield components when compared with no inoculation. They offer the potential to address multiple modes of action, multiple pathogens, and temporal or spatial variability.
15. It is clearly revealed that plant growth, productivity, chemical composition, minerals contents, VAM F spores density and root colonization in pulses can be enhanced by co-inoculating the seeds with the effective rhizobial strains along with VAM fungi.
16. Rock phosphate fertilization can increased the dry matter production of VAM inoculated legumes.
17. Success of the VAM inoculation in the fields affected by effectiveness of indigenous VAMF or depend on VAM inoculums potential which is used.
18. However, applying inoculums to both seed and soil simultaneously proved more effective. More field trial are imperative in different agro-ecological regions to confirm these findings.

5.2 Recommendations

1. Technology adoption of microbial biofertilizers at the local level should be strengthened to fully utilize its potential. With the declining availability of fossil fuels and the price for chemical fertilizers increasing, it is essential for farmers to have greater access to the cheaper mycorrhizal biofertiliser technology.
2. There should be a concerted action to encourage biofertilizer production associated with BNF to become a significant feature of agriculture not only in the national level but in the local level. This would help to overcome chronic problems such as low farm productivity and poor returns on labor.
3. Level of Biocides should also be considered as a determinant to the effectiveness of biofertilizers.
4. The different biofertilizers should be used in combination with 50 to 75% of the recommended fertilizer rates.
5. To achieve efficient use and manipulation of AMF for long-term agricultural stability and productivity in any form of agriculture, our understanding of their physiology and function and their interactions with crops during their vegetative growth and environmental conditions needs to be improved.
6. A study on Rhizosphere is recommended to properly understand the behavior of these plant growths promoting rhizobacteria (PGPR). Identification of the native rhizobial community should also be undertaken to prevent incompatibilities between the rhizobial community and the inoculants as well as the plant cultivar.
7. Utilization of environmentally sound inoculant biofertilizers should be enhanced since their use might help mitigate the onset of global warming as well as reduce the fertilizer input of farmers.
8. Parallel studies should be conducted for identifying low input systems such as organic farming to determine which is more favorable to diazotrophic and AMF communities.
9. Diversified Farm Management (DFM) which are location- specific should be tested to fully realize the potentials of these biofertilizers.

10. It is recommended that to achieve improved productivity through selection of suitable strains of *Rhizobium*, AM fungi and legume combination to obtain inoculants that are compatible and highly competitive.

REFERENCES

REFERENCES

- A.O.A.C. 2000. Official methods of analysis of AOAC international (17th ed.), Association of Official Analytical Chemists, Washington, DC.
- A.O.A.C. 2006. Official Methods of Analysis of the AOAC, 18th Ed., 20 – 22. Washington D.C.
- Abbott, L. M.1982. Comparative anatomy of vesicular-arbuscular mycorrhizas formed on subterranean clover. *Aust. J. Bot.*, 30: 485.
- Abdelgani, M. E., E. A. E. Elsheikh and N. O. Mukhtar.1998. The effect of *Rhizobium* inoculation and chemical fertilization on seed quality of fenugreek seeds. *Food Chem.*, 64(3): 289–293.
- Abdulla, S. andAl-Khaliel.2010. Effects of Arbuscular Mycorrhization in sterile and non-sterile soils. *Tropical Life Sciences Research*, 21(1):55–72.
- Agrios, G. N. 1978. *PlantPathology*. Acad. Press New York, 432-435.
- Ahmed, A.E. and E.A.E. Elsheikh. 1998. Effects of biological and chemical fertilizers on growth and symbiotic properties of faba bean (*Vicia faba* L.) under salt stress. U.K. *J. Agric. Sci.*, 6: 150-164.
- Ahmed, F.E., S.O. Yagoub and E.A.E. Elsheikh. 2000. Effects of mycorrhizal inoculation on the nodulation mycorrhizal infection and yield components of faba bean grown under two different watering regimes.U.K. *J. Agric. Sci.*, 8: 107-117.
- Akhtar, M. S and Z. A. Siddiqui.2009. Effects of phosphate solubilizing microorganisms and *Rhizobium* sp. on the growth, nodulation, yield and root-rot disease complex of chickpea under field condition. *AfricanJournalofBiotechnology*, 8(15): 3489-3496.
- Akiyama, K and H. Hayashi.2006. Strigolactones: chemical signals for fungal symbiosis and parasitic weeds in plant roots. *Ann Bot.*, 97:925–931.
- Akiyama, K., K. Matsuzaki, and H. Hayashi. 2005. Plant sesquiterpenes induce hyphal branching in arbuscular mycorrhizal fungi. *Nature*, 435:824–827.

- Al-Garni, S. M. S. 2006. Increased heavy metal tolerance of cowpea plants by dual inoculation of an arbuscular mycorrhizal fungi and nitrogen-fixer *Rhizobium*. *African J. Biotech.*, 5: 133–42.
- Alguacil, D. M., J. Kohler, F. Caravaca and A. Roldán. 2009. Differential effects of *Pseudomonas mendocina* and *Glomus intraradices* on lettuce plants physiological response and aquaporin PIP2 gene expression under elevated atmospheric CO₂ and drought. *Microb Ecol.*, 58:942–951.
- Ali, M. and S. Kumar. 2006. Pulse production in India. *Yojana*, Sept. 13-15.
- Al-Karaki, G.N. 2006. Benefit, cost and phosphorus use efficiency of mycorrhizal field grown garlic at different soil phosphorus levels. *J. Plant Nutr.*, 25: 1175–84.
- Al-Karaki, G. N. and R. B. Clark, 1998. Growth, mineral acquisition, and water use by mycorrhizal wheat grown under water stress. *J. Plant Nut.*, 21: 263–76.
- Amijee, F., P. B. Tinker, and D. P. Stribley. 1989. The development of endomycorrhizal root systems. VII. A detailed study of effects of soil phosphorus on colonization. *New Phytol.*, 111, 435-446.
- Amir, Y., L. Haennia and A. Youyou. 2007. Physical and biochemical differences in the composition of the seeds of Algerian leguminous crops. *J.F. Comp. Anal.*, 20: 466–471.
- Amjad, I., I.A. Khalil and H. Shah, 2003. Nutritional yield and amino acid profile of rice protein as influenced by nitrogen fertilizer, *Sarhad Journal of Agriculture*, 19 : 127–134.
- Ampofo, T. K. 2008. Growth Response of *Gliricidia Sepium* (Jacq.) Walp to Inoculation With Different arbuscular mycorrhizal (AM) Fungi. *J. Science and Technology*,. 28 (2): 57-65.
- Andrade, G., K. L. Mihara, R. G. Linderman and G. J. Bethlenfalvay. 1998. Soil aggregation status and rhizobacteria in the mycorrhizosphere. *Plant Soil*. 202:89–96.
- Andyking, C. and L.C. Purcell. 2001. Soybean nodule size and relationship to nitrogen fixation response to water deficit. *Crop Sci.*, 41: 1099-1107.
- Antunes, P. M. and M. J. Goss. 2005. Communication in the tripartite symbiosis formed by arbuscular mycorrhizal fungi, rhizobia and legume plants: areview. In: R. Zobel, and

- S. Wright, eds. Roots and soil management: Interactions between roots and the Soil, 199—222.
- Antunes, P. M., D. Deaville and M. J. Goss. 2006. Effect of two AMF life strategies on the tripartite symbiosis with *Bradyrhizobium japonicum* and soybean *Mycorrhiza*. 16: 167–173.
- Antunes, P. M., I. Rajcan and M. J. Goss. 2005. Specific flavonoids as interconnecting signals in the tripartite symbiosis formed by arbuscular mycorrhizal fungi, *Bradyrhizobium japonicum* (Kirchner) Jordan and soybean (*Glycine max* L. Merril.). *Soil Biology & Biochemistry*, 38:533-543.
- Antunes, P. M., K. Schneider, D. Hillis, J. N. Klironomos. 2007. Can the arbuscular mycorrhizal fungus *Glomus intraradices* actively mobilize P from rock phosphates. *Pedobiologia* 51 : 281—286
- Arihara, J. and T. Karasawa. 2000. Effect of Previous crops on arbuscular mycorrhizal formation and growth of succeeding maize. *Soil sci. Plant Nutrition*, 46 (1): 43-51.
- Artursson, V., R. D. Finlay, J. K. Jansson. 2005. Combined bromodeoxyuridine immunocapture and terminal restriction fragment length. *Appl Microbiol Biotechnol*, 89:917–930..
- Artursson, V., R. D. Finlay and J. K. Jansson. 2006. Interactions between arbuscular mycorrhizal fungi and bacteria and their potential for stimulating plant growth. *Environ Microbiol*, 8:1–10.
- Arumugam, R., S. Rajasekaran and S. M. Nagarajan. 2010. Response of Arbuscular Mycorrhizal fungi and *rhizobium* Inoculation on growth and chlorophyll content Of *Vigna unguiculata* (L) Walp Var. Pusa 151. *J. Appl. Sci. Environ. Manage.*, 14 (4) 113 – 115.
- Aryal, U. K., Xu H. L, Fujita M .2003. Rhizobia and AM fungal inoculation improve growth and nutrient uptake of bean plants under organic fertilization. *J Sustain Agric* 21:27–39.
- Asad R., V. Toashih. 2011. Nutrient uptake and yield of chickpea (*Cicer arietinum* L.) inoculated with plant growth promoting rhizobacteria. *AJCS.*, 5(1):44-48.

- Asad, S., K. A. Malik and F. Y. Hafeez. 2004. Competition between inoculated and indigenous *Rhizobium/Bradyrhizobium* spp strains for nodulation of grain and fodder legumes in Pakistan.
- Ashraf, M., M. Mueen-Ud-Din and N. Warrich. 2003. Production Efficiency of mungbean (*Vigna radiata* L.) as affected by Seed inoculation and NPK application. *Intl. J. Agric. Biol.*, 179-180.
- Asimi, S., V. Gianinazzi-Pearson, and S. Gianinazzi. 1989. Influence of increasing soil phosphorus levels on interactions between vesicular-arbuscular mycorrhizae and *Rhizobium* in soybeans. *Can. J. Bot.*, 58:2200–2205.
- Athar, M. 2005. Nodulation of native legumes in Pakistani rangelands. *Agric. Conspect. Sci.*, 70: 49-54.
- Atimanav, G., and A. Adholeya. 2002. AM nocolations of five tropical fodder crops and inoculum production in marginal soil amended with organic matter. *Biology and Fertility of Soil*, 35:214-218.
- Auge , R. M .2001. Water relations, drought and vesicular arbuscularmycorrhizal symbiosis. *Mycorrhiza*, 11:3–42.
- Auge,R.M.2004.Arbuscular mycorrhizae and soil/plant water relations.*Candian journal of soil Sciences*, 84,373-381.
- Azcón, C. Aguilar . 2007. Unravelling mycorrhiza-induced resistance. *Current Opinion in Plant Biology* 10: 393-398.
- Azcon, A, C. and J. M. Barea. 1996.Arbuscularmycorrhizasandbiologicalcontrol of soil-borne plant pathogens—An over view of the mechanisms involved. *Mycorrhiza*, 6: 457–464.
- Azmat, R., R. Talat, S. Qurashi and S. J. Mahmood. 2005. Metal and herbicide toxicity effect on crops and rhizosphere. *Journal-of-the-Saudi-Chemical-Society*, 11(1): 101-109.
- Baba, G. N., A. S. Bali and A. Kumar. 2006. Effect of *Rhizobium* inoculation, nitrogen and phosphorus on productivity of green gram (*Phaseolusradiatus* L.) under temperate agroclimatic conditions of Jammu and Kashmir. *Environment and Ecology*, 24 (Special 3): 715-718.

- Babiker, E. E., E. A. E. Elsheikh, A. G. Osman and A. H. Eltinay. 1995. Effect of nitrogen fixation, nitrogen fertilization and viral infection on yield, tannin and protein contents and in vitro protein digestibility of faba bean. *Plant Foods Human Nutr.*, 47: 257-263.
- Badr S. M. S., El-Din and H. Moawad. 2006. Enhancement of nitrogen fixation in lentil, faba bean, and soybean by dual inoculation with Rhizobia and mycorrhizae. *Plant and Soil*, 117-123.
- Balachandran, S., R. D. Deotale, C. N. Hatmode, P. S. Titare and A. W. Thorat. 2005. Effect of biofertilizers (pressmud, Rhizobium and PSB) and nutrients (NPK) on morpho-physiological parameters of green gram. *J. Soils and Crops.*, 15(2): 442-447.
- Barea J M; Tobar RM; Azcon Anguilar C .1996. Effect of genetically modified *Rhizobium melitoli* inoculant on the development of arbuscular mycorrhizas, root morphology, nutrient uptake and biomass assimilation in *Medicago sativa*. *New Phytologist*. 134 (2): 361-369.
- Barea, J.M., M. Toro, M. O. Orozco, E. Campos and R. Azcón. 2002. The application of isotopic (^{32}P and ^{15}N) dilution techniques to evaluate the interactive effect of phosphate-solubilizing rhizobacteria, mycorrhizal fungi and Rhizobium to improve the agronomic efficiency of rock phosphate for legume crops. *Nutr. Cycl. Agroecosyst.* 63:35-42.
- Barea, J. M., R. Azcon and D. S. Hayman. 1975. Possible synergistic interactions between Endogone and phosphosphate solubilizing bacteria in low phosphate soils. In: Sanders, F.E., Mosse, B., Tinker, P.B. (Eds.), Endomycorrhizas. Academic Press, London. 409–417.
- Barea, J., M. Pozo, R. Azcon and C. Aguilar. 2005. Microbial Co-operation in the rhizosphere. *J Exp Bot.*, 56:1761–1778.
- Beg., M. A. and J. K. Singh. 2009. Effects of biofertilizers and fertility levels on growth, yield and nutrient removal of greengram (*Vigna radiata*) under Kashmir conditions. *Indian-Journal-of-Agricultural-Sciences*, 79(5): 388-390.
- Benizri, E., E. Baudoin and A. Guckert. 2001. Root colonization by inoculated plant growth-promoting rhizobacteria. *Biocontrol Sci Techn.*, 11: 557-574.

- Berg, G. 2009. Plant–microbe interactions promoting plant growth and health: perspectives for controlled use of microorganisms in agriculture. *Appl Microbiol Biotechnol*, 84:11–18.
- Bergero R, Charlesworth . D, Filatov D. A, Moore RC. 2008. Defining regions and rearrangements of the *Silene latifolia* Y chromosome. *Genetics*. 178: 2045–205.
- Bergero, R., L. A. Harrier and P. Franken. 2003. Reporter genes: applications to the study of arbuscular mycorrhizal (AM) fungi and their symbiotic interactions with plant. *Plant and Soil*. 255(1):143-155.
- Bertheau Y., S. G. Azzi-pearson and S. Gianinazzi. 1980. Development expression de l'association endomycorrhizienne chez le ble mise en évidence d'un effet varietal. *Ann. Amélior. Plantes*, 30: 77-79.
- Besserer, A., G. Bécard, C. Roux and N. Séjalon-Delmas. 2009. Role of mitochondria in the response of arbuscular mycorrhizal fungi to strigolactones. *Plant Signal Behav.*, 4:75–77.
- Bharadwaj, D. P., P. O. Lundquist and S. Alstrom. 2008. Arbuscular mycorrhizal fungal spore-associated bacteria affect mycorrhizal colonization, plant growth and potato pathogens. *Soil Biology & Biochemistry*., 40(10):2494-2501.
- Bhat, M. I., A. Rashid, Faisul-ur-Rasool, S. S. Mahdi, S. A. Haq and A. Raies. Bhat. 2010. Effect of *Rhizobium* and *Vesicular arbuscular mycorrhizae* Fungi on Green gram (*Vigna radiata* L. Wilczek) under temperate conditions. *Research Journal of Agricultural Sciences*, 1(2): 113-118.
- Bhat, M. I., S. A. Bangroo, T. Ali, S. R. S. Yadav and M. A. Aziz. 2011. Combined Effects of *Rhizobium* and *Vesicular Arbuscular* Fungi on green gram (*Vigna radiata* L. Wilczek) under temperate conditions. *Research Journal of Agricultural Sciences*, 2(1): 17-20.
- Bhat, S. A., O. V. S. Thenua, B. G. Shivakumar, J. K. Malik. 2005. Performance of summer greengram [*Vignaradiata* (L.) Wilczek] as influenced by biofertilizers and phosphorus nutrition. *Haryana-Journal-of-Agronomy*, 21(2): 203-205.
- Bhatty, R. S. 1984. Relationship between physical and chemical characters and cooking quality in lentil. *J. Agric. Food Chem.*, 32:1161.

- Bhuiyan, M. A. H. 2004. Evaluation of introducing mungbean into cereal based cropping pattern for sustainable soil fertility and productivity. Ph. D. Thesis, Dept of Soil Sci., Bangladesh Agril. Univ., Mymensingh, Bangladesh. 1-2 17.
- Bhuiyan. M. A. H., M. H. Mian And M.S. Islam. 2008. Studies On The Effects Of *Bradyrhizobium* Inoculation on yield and yield attributes of mungbean. *Bangladesh J. Agril. Res.*, 33(3): 449-45.
- Bianciotto, V., S. Andreotti, R. Balestrini, P. Bonfante and S. Perotto. 2001. Mucoid mutants of the biocontrol strain *Pseudomonas fluorescens* CHA0 show increased ability in biofilm formation on mycorrhizal and nonmycorrhizal carrot roots. *Mol Plant-Microb Interact.*, 14:255-260.
- Bloen, J.F. and I.J. Law. 2001. Determination of competitive abilities of *Bradyrhizobium*
- Boddington, C. L., J. C. Dodd. 2000. The effect of agricultural practices on the development of indigenous arbuscular mycorrhizal fungi. II. Studies in experimental microcosms. *Plant and Soil*, 218:145-157.
- Bonfante, P. 2003. Mycorrhizal fungi and endobacteria: a dialog among cells and genomes. *Biol Bull.*, 204:215-220
- Bonfante, P. and A. Genre .2008. Plants and arbuscular mycorrhizal fungi: an evolutionary-developmental perspective. *Trends Plant Sci.*, 13:492-498.
- Borowicz, V.A. 2001. Do arbuscular mycorrhizal fungi alter plant-pathogen relations?. *Ecology*, 82, 3057-3068.
- Bressan, W., J. O. Siqueira, C. A. Vasconcellos, A. A. C. Purcino. 2001. Fungos micorrizicos fosforo, no *crescimento*, no teor de nutrientes e na producao do sorgo e soja consorciados. *Pesqui. Agropecu. Bras.* 36: 315-323.
- Brundrett, M. 1990. Mycorrhizas in natural ecosystem, *Adv. Ecol. Res.* 21 : 171-313.
- Cabello, M., G. Irrazabal, A. M. Bucsinszky, M. Saparrat, S. Schalamuk. 2005. Effect of an arbuscular mycorrhizal fungus, *Glomus mosseae*, and a rock-phosphatesolubilizing fungus, *Penicillium thomii*, on *Mentha piperita* growth in a soilless medium. *J. Basic Microbiol.* 45, 182-189.
- Callaway, R. M., G. C. Thelen, S. Barth, P. W. Ramsey, J. E. Gannon. 2004. Soil fungi alter interactions between the invader *Centaurea maculosa* and North American natives. *Ecology*, 85, 1062-1071.

- Caravaca, F., M. M. Alguacil, R. Azco'n, G. Diaz, A. Rolda'n. 2004. Comparing the effectiveness of mycorrhizal inoculation and amendment with sugar beet, rock phosphate and *Aspergillus niger* to enhance field performance of the leguminous shrub *Dorycnium pentaphyllum* L. *Appl. Soil Ecol.*, 25, 169–180.
- Cardoso, I.M. and T.W. Kuyper, 2006. Mycorrhiza and tropical soil fertility. *Agric. Ecosyst. Environ.*, 116: 72–84.
- Carrenho, R., E.S. Silva, S.F.B. Trufem and V.L.R. Bonani. 2001. Successive cultivation of maize and agricultural practices on root colonization, number of spores and species of arbuscular mycorrhizal fungi. *Bras. J. Microbiol.*, 32: 262-270.
- Cavagnaro, T.R., L.E. Jackson, J. Six, H. Ferris, S. Goyal, D. Asami and K.M. Scow. 2006. Arbuscular mycorrhizas, microbial communities, nutrient availability and soil aggregates in organic tomato production. *Plant Soil*, 282: 209–25.
- Chakraborty, P. F. Sosulski and A. Bose. 1979. Ultracentrifugation of salt soluble proteins in ten legume species, *Journal of the Science of Food and Agriculture*, 30 : 766–771.
- Chalk, P. M. R. de F. Souza, S. Urquiaga, B. J. R. Alves and R. M. Boddey. 2006. The role of arbuscular mycorrhiza in legume symbiotic performance, *Soil Biology & Biochemistry*, 38: 2944–2951.
- Charitha, D. M., M. N. Reddy. 2001. Growth response of groundnut to VAM fungus and *Rhizobium* inoculation. *Plant pathology Bulletin*, 10: 71-78.
- Chatterjee, A. and P. Bhattacharjee. 2002. Influence of combined inoculation with *Rhizobium* and phosphobacteria on mungbean in field. *Journal-of-Mycopathological-Research*, 40(2): 201-203.
- Chebotar, V. K., C. A. Asis Jr and S. Akao .2001. Production of growth-promoting substances and high colonization ability of rhizobacteria enhance the nitrogen fixation of soybean when coinoculated with *Bradyrhizobium japonicum*. *Biol Fert Soils.*, 34: 427-432.
- Chen X., J.J. Tang, G.Y. Zhi and S.J. Hu. 2005. Arbuscular mycorrhizal colonization and phosphorus acquisition of plants: effects of coexisting plant species. *Appl. Soil Ecol.*, 28: 259-269.

- Chen, B. D., X. L. Li, H. Q. Tao, P. Christie and M. H. Wong. 2003. The role of arbuscular mycorrhiza in zinc uptake by red clover growing in calcareous soil spiked with various quantities of zinc. *Chemosphere* 50(6): 839-846.
- Clark, R.B., Zeto, S.K., 2000. Mineral acquisition by arbuscular mycorrhizal *Plants*. *J.Plant Nutr.*, 23, 867–902.
- Cone, J.W., A.H. Van Gelder, H. Bachman and V. A. Hindle. 2002.Comparison of organic matter degradation in several feedstuffs in the rumen as determined with the nylon bag and gas production technique. *Anim. Feed. Edi. Technol.*, 96: 56–67.
- Cordier, C., M. J. Pozo., J. M. Barea., S. Gianinazzi and V.G.Pearson.1998.Cell defence responses associated with localized and systematic resistance to *Phytophthora parasitica* induced by an arbuscular mycorrhizal fungus. *Molecular plant microbe interactions*. 11: 1017-1028.
- Costa,G.E. K. Queiroz-Monici, S. Reis and A.C. Oliveira.2006. Chemical composition, dietary fiber and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes, *Food Chemistry* 94: 327–330.
- Covacevich, F., H. E. Echeverria and L. A. N. Aguirrezabal. 2007. Soil available phosphorus status determines indigenous mycorrhizal colonization of field and glasshouse-grown spring wheat from Argentina. *Appl. Soil Ecol.*, 35:1-9.
- Dalpe, V. 1993. Sand Sampling and method of analysis (M.R. Carter, ed.). *Cand. Soc. Soil.*
- Dalpe,Y.,2005.Mycorrhizae:a potential tool for plant protection but nota panacea. *Phyto protection*86: 53–59.
- Das, K. Tanushree T., Debidas G.and D. K. Nandi.2009.New experimental design: dehydration induced uremia and oxidative stress on male albino rats, innovative approach to researchers for further study on kidney disease.*Pharmacologyonline* 3: 882-892.
- Dashti, N., F. Zhang, R. Hynes, D. L. Smith .1998. Plant growthpromoting rhizobacteria accelerate nodulation and increase nitrogen fixation activity by field grown soybean [*Glycine max* (L) Merr.] under short season conditions. *Plant Soil*, 200: 205-213

- De Boer, W., L. B. Folman, R. C. Summerbell and L. Boddy. 2005. Living in a fungal world: impact of fungi on soil bacterial niche development. *FEMS, Microbiol Rev.*, 29:795–811.
- De Miranda, J.C.C., Harris, P.J. & Wild, A. 1989. Effects of soil and plant phosphorus concentrations on vesicular-arbuscular mycorrhizae in sorghum plants. *New Phytologist*, 112:405-410.
- Devi, M. C and M. N. Reddy. 2001. Growth response of groundnut to VAM fungus and *Rhizobium* inoculation. *Plant Pathol. Bulletin.*, 10(2): 71-78.
- Dhage, V. J., B. T. Shete, A. D. Tambe and H. M. Patil. 2008. Effect of integrated nutrient management on microbial count and protein content of kabuli chickpea. *J. Maharashtra-Agricultural-Universities*, 33(2): 265-266.
- Dileep-Kumar, B.S., I. Berggren and A.M. Martensson, 2001. Potential for improving pea production by co-inoculation with fluorescent *Pseudomonas* and *Rhizobium*. *Plant and Soil*, 229: 25-34.
- Dudde, K. B. and R. S. Raut. 2005. Combined effects of *Rhizobium* and VA-mycorrhiza inoculation on groundnut. *Journal of Soils and Crops*, 15(2): 315-318.
- Dumbrell, A., M. Nelson, T. Helgason, C. Dytham and A. Fitter. 2010. Relative roles of niche and neutral processes in structuring a soil microbial community. *ISME J* 4:337–345.
- Duponnois, R., A. Colombet, V. Hien and J. Thioulouse. 2006. The mycorrhizal fungus *Glomus intraradices* and rock phosphate amendment influence plant growth and microbial activity in the rhizosphere of *Acacia holosericea*. *Soil Biol. Biochem.*, 37: 1460-1468.
- El-Ghandour, I.A., M.A.O. El. Sharawy and E. M. Abdel-Moniem. 1996. Impact of vesicular arbuscular mycorrhizal fungi and *Rhizobium* on the growth and P, N and Fe uptake by faba-bean. *Fertilizer Research*, 43: 43-48.
- El-Habbasha, S. F., A. A. Kandil, N. S. Abu Hagaza, A. K. A. El Haleem, M. A. Khalafallah, and T. G. Behairy. 2005. Effect of phosphorus levels and some bio-fertilizers on dry matter, yield and yield attributes of groundnut. *Bulletin of Faculty of Agriculture, Cairo University*. 56(2): 237-252.

- Elsen, A., H. Baimey, R. Swennen and D. De Waele. 2003. Relative Mycorrhizal dependency and mycorrhizal-nematode interaction in banana cultivars (*Musa* sp.) differing in nematode susceptibility. *Plant and Soil*, 256, 303-313.
- Elsheikh, E. A. E. 1998. A note on the effects of fertilization on the seed quality of faba bean. *Univ. Khartoum J. Agric. Sci.*, 6, 167-172.
- Elsheikh, E. A. E. and E. I. A. Ahmed, 2000. A note on the effect of intercropping and *Rhizobium* inoculation on the seed quality of faba bean (*Vicia faba* L.). U.K. *J. Agric. Sci.*, 8: 157-163.
- Elsheikh, E.A.E. and A.A. Elzidany. 1997. Effects of *Rhizobium* inoculation, organic and chemical fertilizers on yield and physical properties of faba bean seed. *Pl. Food Hum. Nutr.*, 51: 137-44.
- Erdal, I., M. A. Askin, Z. kuçukyumuk, F. Yildirim, and A. Yildirim. 2008. Rootstock has an important role on iron nutrition of apple trees. *World J. Agricultural Sciences*, 4 (2): 173-177.
- Ereifej, K.I., G. N. Al-Karaki and M. K. Hammouri. 2001. Seed chemical composition of improved chickpea cultivars grown under semiarid Mediterranean conditions', *Int. J. Food Prop.*, 4: 239-246.
- Ezawa, T., K. Yamamoto and S. Yoshida. 2000. Species composition and spore density of indigenous vesicular arbuscular mycorrhizal fungi under different condition of P-fertility as revealed by soybean trap culture. *Soil Sci. and Plant nutrition*, 46 (2): 297.
- Farshadfar, E. and M. Farshadfar. 2008. Genetic variability and path analysis of Chickpea (*Cicer arietinum* L.) Landraces and Lines. *J. Appl. Sci.*, 8: 3951-3956.
- Fatima, Z., M. Zia and M. F. Chaudhary. 2006. Effect of *Rhizobium* strains and phosphorus on growth of soybean (*Glycine max*) and survival of *Rhizobium* and P solubilizing bacteria. *Pak. J. Bot.*, 38(2): 459-464.
- Fatma T, P. Suriyakup, Hélène Vailhe1, Jan Jansa and Jean-Jacques Drevon. 2009. Assess suitability of hydroaeroponic culture to establish tripartite symbiosis between different AMF species, beans, and rhizobia. *BMC Plant Biology*, 9:73.

- Fatma T., Porntip Suriyakup, Hélène Vailhe, Jan Jansa and Jean-Jacques Drevon.2009. Assess suitability of hydroaeroponic culture to establish tripartite symbiosis between different AMF species, beans, and rhizobia. *BMC Plant Biology* , 9:73.
- Fattah, G.M.A. and A.A.Razak.1996.Functional Activity of VA-mycorrhiza (*G.mosseae*) in the growth and productivity of soybean plants grown in sterilized soil proceeding of the first International conference on fungi. Cairo Egypt. *African. J. Mycol. and Biotechnology*, 4(2): 1-12.
- Feddermann, N., R. Finlay, T. Boller, and M. Elfstrand. 2010. Functional diversity in arbuscular mycorrhiza - the role of gene expression, phosphorous nutrition and symbiotic efficiency. *FungalEcology*, 3: 1-8.
- Feng, G., M. Yang and D. Baj.1998. Influence of VAM fungi on elements concentration in *Bromus inermis* under salinity stress. *Acta. Prataculturae Sinica*. 7: 3, 21- 28.
- Filion, M., M. St-Arnaud and J. A. Fortin.1999.Direct interaction between the arbuscular mycorrhizal fungus *Glomus intraradices* and different rhizosphere microorganisms. *New Phytologist*, 141,525–533.
- Filion, M., M. St-Arnaud and S. H. Jabaji-Hare. 2003.Quantification of *Fusarium solani* f. sp phaseoli in mycorrhizal bean plants and surrounding mycorrhizosphere soil using real-time polymerase chain reaction and direct isolations on selective media. *Phytopathology* 93,229–235.
- Franzini, V. I., R. Azcon, F. L. Mendes and R. Aroca. 2009. Interactions between *Glomus* species and *Rhizobium* strains affect the nutritional physiology of drought-stressed legume hosts. *Journal of Plant Physiology* ,167 (8), 15: 614-619.
- Franzini, V., R. Azcon, F. Mendes and R. Aroca.2010. Interactions between *Glomus* species and *Rhizobium* strains affect the nutritional degradation, soil phosphatase and dehydrogenase activities, and soil microbial community structure. *Soil Biol Biochem.*, 41:726–734.
- Frey-Klett, P., J. Garbaye and M. Tarkka. 2007. The mycorrhiza helper bacteria revisited. *New Phytol.*, 176:22–36.
- Gadkar, V., R.D. Schwartz, T. Kunik and Y. Kapulnik, 2001. Arbuscular mycorrhizal fungal colonization. Factors involved in host recognition. *Plant Physiol.*, 127: 1493–9.

- Galal, Y.G. M., I. A. El-Ghandour, S. S. Aly, S. Soliman and A. Gadalla. 2000. Non-isotopic method for the quantification of biological nitrogen fixation and wheat production under field conditions. *Biology and Fertility of Soils* 32: . 47–51.
- Galyean, M. 1985. *Techniques and Procedures in Animal Nutrition Research*. New Mexico State University, Deptt. Animal & Range Conditions.
- Ganry, F., H. G. Diem and Y. R. Dommergues. 1982. Effect of inoculation with *Glomus mosseae* on nitrogen fixation by field grown soybeans. *Plant Soil*, 47:713–715
- Ganskopp, D. and D. Bohnert. 2001. Nutritional dynamics of 7 northern Great basin grasses. *J. Range Manage.*, 54: 640-647.
- Garbaye, J .1994. Helper bacteria a new dimension to the mycorrhizal symbiosis. *New Phytol.*, 128:197–210.
- Garni, M.S., 2006. Increased heavy metal tolerance of cowpea plants by dual inoculation of an arbuscular mycorrhizal fungi and nitrogen-fixer *Rhizobium*. *African J. Biotech.*, 5: 133–42.
- Gavito, M. E., P. S. Curtis, T. N. Mikkelsen and I. Jakobsen. 2000. Atmospheric CO₂ and mycorrhiza effects on biomass allocation and nutrient uptake of nodulated pea (*Pisum sativum* L) plants. *J. of Experimental Botany*, 51(352): 1931-1938.
- Geneva, M., G. Zehirov, E. Djonova, N. Kaloyanova, G. Georgiev and I. Stancheva. 2006. The effect of inoculation of pea plants with mycorrhizal fungi and *Rhizobium* on nitrogen and phosphorus assimilation. *Plant Soil Environ.*, 52, (10): 435–440.
- George, E. 2000. Nutrient uptake, In: Arbuscular mycorrhizas: Physiology and function. Eds: Y. Kappulnick and D.D Douds Jr. Kluwer Academic press, : 307-344.
- George, E., H. Marschner and I. Jakobsen. 1995. Role of arbuscular mycorrhizal fungi in uptake of phosphorus and nitrogen from soil. *Critical Reviews in Biotechnology*, 15
- Gerdemann, J. W. and T.W. Nicolson. 1963. Spores of mycorrhizal *Endogone* species extracted from soil by wet sieving and decanting method. *Trans. Br. Mycos. Soc.*, 46:235-245.
- Ghosh, M. K. and S. A. Joseph. 2008. Influence of biofertilizers, foliar application of DAP and sulphur sources on yield and yield attributes of summer green gram (*Vigna radiata* L. Wilczek). *Legume-Research*, 31(3): 232-233.

- Gilani, S. N. and R. Bharose. 2004. Effect of bio-fertilizers on the enrichment of soil fertility with special reference to soil phosphorus status and its effect on yield of green gram (*Vigna radiata* L.). *New-Agriculturist.*, 15(1/2): 129-131
- Giller, K. E. 2001. Nitrogen fixation in tropical cropping systems. Wallingford, London.
- Giovannetti, M. and B. Mosse. 1980. An evaluation of techniques for measuring VAM infection in roots. *New Phytol.*, 84:489-500.
- Gitasree, G. 2007. Potential for improving chickpea production by inoculation with fluorescent pseudomonads and Cicer-Rhizobium. *Journal-of-Mycopathological-Research.* 45(2): 293-295.
- Glick, B. R. 2005. Modulation of plant ethylene levels by the bacterial enzyme ACC deaminase. *FEMS Microbiol Lett* 252:1-7.
- Goenadi, D. H. and Y. S. Sugiarto. 2000. Biocativation of poorly soluble phosphate rocks with phosphorus-solubilizing fungus. *Soil Sci. Soc. Am. J.*, 64, 927-932.
- Gomaa, A.O. and H.E. Abou-Aly. 2001. Efficiency of biofertilization in the presence of both inorganic and organic fertilizers on growth, yield and chemical constituents of anise plant (*Pimpinella anisum* L.). Proc. of the fifth Arabian Hort. Conf. Ismailia, Egypt, March. 24-28 :73-80.
- González, O. García, J. M. Larruga and V. M. Cabrera. 2006. The mitochondrial lineage U8a reveals a Paleolithic settlement in the Basque country. *BMC Genomics*, 7:124
- Gosling, P., A. Hodge, G. Goodlass, G. D. Bending. 2006. Arbuscular mycorrhizal fungi and organic farming. *Agric Ecosyst Environ.*, 113:17-35.
- Goss, M.J., A. de Varennes, P.S. Smith, and J.A. Ferguson. 2002. N₂ fixation by soybeans grown with different levels of mineral nitrogen, and the fertilizer replacement value for a following crop. *Can. J. Soil Sci.*, 82:139-145.
- Goud, R. P and B. B. Reddy. 2007. Effect of Rhizobium inoculation, plant population and phosphorus on growth and yield of summer greengram (*Phaseolus radiatus* L.). *Progressive-Research.* 2(1/2): 175-176.
- Govindarajulu, M., P. E. Pfeffer, H. Jin, J. Abubaker, D. D. Douds, J. W. Allen, H. Bücking, P. J. Lammers and Y. S. Hill. 2005. Nitrogen transfer in the arbuscular mycorrhizal symbiosis. *Nature*, 435:819-823.

- Grandimaison, J., G. M. Olah., M. R. Vancalsteren and V. F Urlan.1993. Characterization and localization of plant phenolics likely involved in the pathogen resistance expressed by endomycorrhizal roots. *Mycorrhiza*. 3: 155-164.
- Griffiths, R. I., M. Manefield, N. Ostle, N. McNamara , A. G. O'Donnell, M. J. Bailey and A. Whiteley. 2004. $^{13}\text{CO}_2$ pulse labelling of plant in tandem with stable isotope probing: methodological considerations for examining microbial function in the rhizosphere. *J Microbiol Methods*., 58:119–129.
- Grunwald, U., W. Guo, K. Fischer, S. Isayenkov, L. Müller, B. J. Hause, X. Yan, H. Küster and P. Franken. 2009. Overlapping expression patterns and differential transcript levels of phosphate transporter genes in arbuscular mycorrhizal, Pi-fertilised and phytohormone-treated *Medicago truncatula* roots. *Planta*, 229: 1023–1034.
- Gryndler, M. and V. Vancura. 1991. The effects of long continued P fertilizer of the soil on the capability of VAM fungi to colonize maize roots. *Restlina-Vyroba*. 37: 1, 69-73.
- Gryndler, M., H. Hrselova and D. Striteska. 2000. Effect of soil bacteria on hyphael growth of the arbuscular mycorrhizal fungus *Glomus claroideum*. *Folia Microbiol* ., 45:545–551.
- Gueguen, J. and J. Barbot. 1988. Quantitative and qualitative variability of pea (*Pisum sativum* L.) protein composition, *Journal of the Science of Food and Agriculture*, 42: 209–224.
- Guinel, F.C. and R. D. Geil. 2002. A model for the development of the rhizobial and arbuscular mycorrhizal symbioses in legumes and its use to understand the roles of ethylene in the establishment of these two symbioses. *Botany*, 80:695-720.
- Gull, M., F. Y. Hafeez, M. Saleem, and K. A. Malik. 2004. Phosphorus uptake and growth promotion of chickpea by co-inoculation of mineral phosphate solubilizing bacteria and a mixed rhizobial culture. *Australian Journal of Experimental Agriculture*, 44: 623–628.
- Gupta, R. and S. Dhillon.1993a. Characterization of seed storage proteins of Lentil (*Lens culinaris* M.), *Annals of Biolog.y*, 9: 71–78.
- Gupta, S. C.2004. Response of gram (*Cicer arietinum*L.) to types and methods of microbial inoculation. *Indian-Journal-of-Agricultural-Sciences*, 74(2): 73-75.

- Guriqbal, S., H.S. Sekhon, S. Poonam, G. Singh, and P. Sharma. 2001. Effect of Rhizobium, Vesicular arbuscular mycorrhiza and phosphorus on the growth and Yield of lentil (*Lens culinaris*) and field pea (*Pisum sativum*). *Envirment and Ecology*, 19 (1): 40-42.
- Gutjahr, C., Casieri, L., U. Paszkowski. 2009. *Glomus intraradice* induces changes in root system architecture of rice in dependently of common symbiosis signaling. *New Phytologist*, 182,829–837.
- Gyaneshwar, P., G. N. Kumar, L. J.Parekh and P. S. Poole. 2002. Role of soil microorganisms in improving P nutrition of plants. *Plant Soil*, 245: 83–93.
- Habte, M. and N. W. Osorio. 2002. Mycorrhizas: Producing and Applying Arbuscular Mycorrhizal Inoculation. Ecoliving Center. Overstory # 102 <http://www.Ecoliving.Cat.Org.au>
- Hafeez, F.Y., N. H. Shah and K.A. Malik. 2000. Field evaluation of lentil cultivars inoculated with Rhizobium leguminosarum bv. *viciae* strains for nitrogen fixation using nitrogen-15 isotope dilution. *Biol Fertil Soils*, 31: 65-69.
- Hall, I. R. and B .J. Fish .1979.A key to the Endogonaceae. *Trans.Br.Mycol.Soc.*, 73-261.
- Hamaoui, B., J. M. Abbadi, S. Burdman, A. Rashid, S. Sarig, andY. Okon. 2001. Effects of inoculation with *Azospirillum brasilense* on chickpeas (*Cicer arietinum*L.) and faba beans (*Vicia faba*) under different growth conditions. *Agronomie.*, 21: 553–560.
- Hani, A. AL-Zalzaleh, Majid A. AL-Zalzaleh, A. R. Mathew.2009. Vam Inoculation for Selected Ornamental Plants in Bioremediated and Agricultural Soils.*European Journal of Scientific Research*,25 (4): 559-566.
- Hanif, N. Q., M. Naseem, S. khatoon and N. Malik .2006. Prevalence of mycotoxins in poultry rations. *Pakistan Journal of Science and Industrial Research*, 49: 120-124.
- Harley, J. L. and S. E. Smith .1983. Mycorrhizal symbiosis. Academic Press, London UK.PP. 488.
- Harrison, M. J. 2005. "Signaling in the arbuscular mycorrhizal symbiosis". *Annu Rev Microbiol*, 59: 19–42.

- Hart, M. M. and R. J. Reader. 2002. Taxonomic basis for variation in the colonization strategy of arbuscular mycorrhizal fungi. *New Phytol.*, 153: 335–344.
- Hartmann, A., M. Schmid, D. van Tuinen and G. Berg. 2009. Plant-driven selection of microbes. *Plant Soil*, 321: 235–257.
- Hause, B., C. Mrosk, S. Isayenkov and D. Strack. 2007. Jasmonates in arbuscular mycorrhizal interactions. *Phyto chemistry.*, 68: 101–110.
- Hawkins, H. J., A. Johansen, and E. George. 2000. Uptake and transport of organic and inorganic nitrogen by arbuscular mycorrhizal fungi. *Plant Soil*, 226:275-285.
- Hayman, D.S., 1970. Endogone spore numbers in soil and Vesicular Arbuscular Mycorrhizae in wheat as influenced by season and soil treatment. *Trans. Br. Mycol. Soc.*, 54 (1), 53-63.
- Heggo, A. M. and F.N. Barakah.2004. Effects of Inoculum Densities of *Rhizobium Meliloti* and different rates of nitrogen fertilizers on Alfalfa plants grown in calcareous soil. *J. King Saud Univ. Agric. Sci.*, 16 (2) : 161-170.
- Henshaw.F.O.2008. Varietal Differences in Physical Characteristics and Proximate Composition of Cowpea (*Vigna unguiculata*).*World Journal of Agricultural Sciences*. 4 (3): 302-306.
- Henzell, E.F. 1988. The role of biological nitrogen fixation research in solving problems in tropical agriculture. *Pl. Soil.*, 108: 15–21.
- Hodge, A. 2000. Microbial ecology of the arbuscular mycorrhiza. *FEMS Microbiology Ecology*, 32(2): 91-96.
- Hodge, A., C. D. Campbell and A. H. Fitter. 2001. An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. *Nature*, 413, 297–299.
- Hu, F.B. 2003. Plant-based foods and prevention of cardiovascular disease: An overview, *American Journal of Clinical Nutrition*, 78: 544–551.

- Hussain, A., A. Ali, J. Akhtar and M. Yasin. 2010. Effects of phosphorus in combination with *rhizobium* inoculation on growth and yield parameters of mungbean. *Crop & Environment*, 1(1): 53-56.
- Hussain, J., N. U. Rehman, A. L. Khan, M. Hamayun, S. M. Hussain and Z. K. Shinwari. 2010. Proximate and essential nutrients evaluation of selected vegetables species from Kohat region, Pakistan. *Pak. J. Bot.*, 42(4): 2847-2855.
- Hussain, J., Riaz Ullah, N. U. Rehman, A. L. Khan. Z. Muhammad, F. U. Khan, S. T. Hussain and S. Anwar . 2010. Endogenous transitional metal and proximate analysis of selected medicinal plants from Pakistan. *Journal of medicinal plants research*, 4(3), 267-270.
- Ibibijen, J., S. Urquiaga, M. Ismaili, B. J. Alves and R. M. Boddey. 1996. Effect of arbuscular mycorrhizal fungi on growth, mineral nutrition and nitrogen fixation of three varieties of common beans (*Phaseolus vulgaris*). *New Phytol.*, 134, 353–360.
- Iqbal, S. H., Shahjahan, F. Bareen and G. Nasim. 1991. Mycorrhizae of the leguminosae IV. Vesicular arbuscular mycorrhizal infection in root nodules of some common leguminous weeds. *Pakistan. J. Agric. Res.*, 12, (3) :206.
- Isayenkov, S., C. Mrosk, I. Stenzel, D. Strack and B. Hause. 2005. Suppression of allene oxide cyclase in hairy roots of *Medicago truncatula* reduces jasmonate levels and the degree of mycorrhization with *Glomus intraradices*. *Plant Physiol.*, 139:1401–1410.
- Ishida, T., Aida, M., Takada, S., and Tasaka, M. 2000. Involvement of cup-shaped cotyledon genes in gynoecium and ovule development in *Arabidopsis thaliana*. *Plant Cell Physiol.*, 41, 60–67.
- Izaguirre Mayoral, M. L., O. Carballo, L. Carreno, M. G. d. Mejia, and M. G. de Mejia. 2000. Effects of VA Mycorrhizal inoculation on growth, yield, N and P nutrition of nodulating bean varieties in two soil substrates of contrasting fertility. *J. of Plant Nutrition*, 23 (8): 1117-1133.

- Jacobs, D.R. and D.D. Gallaher.2004. Whole grain intake and cardiovascular disease, A review: Current Atherosclerosis Reports6 : 415–423.
- Jagvir, S., M. S. Deshmukh and N. R. Tandulkar. 2004. Direct and Residual effect of sulphur in cotton-wheat cropping system in sandy soil. *Fertilizer News*, 49: 61-63.
- Jain, A. K., R. Kumar, O. P. Singh, J. D. S. Panwar and V. Kumar. 2008. Dual inoculation of *Rhizobium* and vesicular arbuscular mycorrhizal (VAM) with phosphorus in mung bean (*Vignaradiata*). *PlantArchives.*, 8(2): 945-946.
- Jain, A. K., S. Kumar and J. D. Panwar. 2008. Effect of phosphorus and micronutrients with seed inoculation on green gram (*Vignaradiata* (L.) Wilczek). *Advances-in-Plant-Sciences*, 21(1): 295-297.
- Jain, A. K., S. Kumar and J. D. S. Panwar. 2007. Role of *Rhizobium*, phosphorus and micronutrients on growth and modulation of green gram (*Vigna radiata* (L.) Wilczek). *Advances-in-Plant-Sciences.*, 20(2): 337-339.
- Jain, A. K., S. Kumar, J. D. S. Panwar and R. K. Jain .2009. Seed vigour affected by phosphorus and micronutrients with *Rhizobium* inoculation in mung bean (*Vigna radiata*). *Advances-in-Plant-Sciences*, 22(1): 309-310.
- Jain, L. K., P. Singh and J. K. Balyan. 2005. Nutrient balance sheet in gram (*Cicer arietinum* L.) under influence of phosphorus and biofertilizers. *Haryana-Journal-of-Agronomy*. 21(1): 77-78.
- Jain, L. K., S. Pushpendra. 2003. Growth and nutrient uptake of chickpea (*Cicer arietinum* L.) as influenced by bio-fertilizers and phosphorus nutrition. *Crop Research Hisar*. 25(3): 410-413.
- Jalaluddin, M. 2005. Effect of inoculation with VAM fungi and *Bradyrhizobium* on growth and yield of soybean in sindh. *Pak. J. Bot.*, 37(1): 169- 173.
- Jalaluddin, M. and Q. M. K. Anwar.1991.VAM fungi in wheat and rice field. *Pak. J. Bot.*,37(1):169-173.
- Jalili, F., K. Khavazi, E. Pazira, A. Nejati A, H. A. Rahmani, H. R. Sadaghiani and M. Miransari. 2009. Isolation and characterization of ACC deaminase producing fluorescent pseudomonads, to alleviate salinity stress on canola (*Brassica napus* L.) growth. *J Plant Physiol* ., 166:667–674.

- Jamal, A. and K. Naser. 2002. Customer satisfaction and retail banking an assesment of some of the key antecedents of customer satisfaction in retail banking. *International Journal of Bank Marketing*, 20 (4), 146–160.
- Janoušková, M., M. Vosátka, L. Rossi and N. L. Moulin, 2007. Effects of arbuscular mycorrhizal inoculation on cadmium accumulation by different tobacco (*Nicotiana tabacum* L.) types. *Appl. Soil Ecol.*, 35: 502–10.
- Jarande, N. N., P. S. Mankar, V. S. Khawale, A. A. Kanase and J. T. Mendhe .2006. Response of chickpea (*Cicer arietinum* L.) to different levels of phosphorus through inorganic and organic sources. *Journal-of-Soils-and-Crops.*, 16(1): 240-243.
- Jat, R. S. and I. P. S. Ahlawat. 2006. Direct and residual effect of Vermicompost, biofertilizers and phosphorus on soil nutrient dynamics and productivity of chickpea-fodder maize sequence. *Journal-of-Sustainable-Agriculture*, 28(1): 41-54
- Javaid, A. and T. Riaz, 2008. Mycorrhizal colonization in different varieties of *gladiolus* and its relation with plant vegetative and reproductive growth. *Int. J. Agri. Biol.*, 10:278:82.
- Javaid, A., T. Riaz and S.N. Khan, 2007. Mycorrhizal status of *Narcissus papyraceus* Ker-Gawl. co-cultivated with *Cynodon dactylon* Pers. *Int. J. Agric. Biol.*, 9: 901–4
- Jeffries, P. and J. M. Barea. 2001Arbuscular mycorrhiza: a key component of sustainable plant–soil ecosystems. In: Hock B (ed) *The Mycota: fungal associations*, vol IX. Springer, Berlin, :95–113.
- Jia, Y., V. M. Gray, C. J. Straker. 2004. The influence of *Rhizobium* and arbuscular mycorrhizal fungi on nitrogen and phosphorus accumulation by *Vicia faba*. *Annals of Botany*, 94:251-258.
- Jin, H., P. E. Pfeffer, D. D. Douds, E. Piotrowski, P. J. Lammers and Y. Shachar-Hill. 2005. The uptake, metabolism, transport and transfer of nitrogen in an arbuscular mycorrhizal symbiosis. *New Phytol.*, 168:687-696.
- Johansson, J. F., L. R. Paul, and R. D. Finlay, R. D. 2004. Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture. *FEMS Microbiol. Ecol.*, 48:1-13.
- John, B. N. 2002. Arbuscular mycorrhizae interaction in plants, rhizosphere. Science publishers, Inc: Enfield (NH),USA/Plymouth. UK. 47-63.

- Johnson, A. K., J. L. Morrow-Tesch, and J. J. McGlone. 2001. Behavior and performance of lactating sows and piglets reared indoors or outdoors. *J. Anim. Sci.*, 79:2571-2579.
- Joner, E. and C. Leyval. 2009. Phytoremediation of organic pollutants using mycorrhizal plants: a new aspect of rhizosphere interactions. In: Lichtfouse E, Navarrete M, Debaeke P, Véronique S, Alberola C (eds) Sustainable agriculture. Springer, The Netherlands: 885–894.
- Joner, E. J. 2000. The effect of long term fertilization with organic and inorganic fertilizers on mycorrhiza mediated P uptake in subterranean clover. *Biology and fertility of Soil*, 32: 435-440.
- Joyce Boye, Fatemeh Z., and A. Pletch. 2010. Pulse proteins: Processing, characterization, functional properties and applications in food and feed .food research international. 43, (2): 414-431.
- Kalipada, P. and R. K. Singh. 2003. Effect of levels and mode of phosphorus application with and without biofertilizers on yield and nutrient uptake by chickpea (*Cicer arietinum* L.) *Annals. of. Agricultural research*, 24 (4): 768-775.
- Kandeel, Y.M., F.A. Menesy, M. M. Khalafalla and W.M..Gad. 2004. Effect of some commercial biofertilizer on growth seed, volatile oil yield and chemical composition of *Anethum graveolens* L. *J. Agric. Res.* 30(3):721-737.
- Kantar, F., E. Elkoca, H. Ogutcu, and O. F. Algur. 2003. Chickpea yields in relation to *Rhizobium* inoculation from wild chickpea at high altitudes. *Journal of Agronomy and Crop Science* 189: 1–7.
- Karaki. A., G.N., 2006. Benefit, cost and phosphorus use efficiency of mycorrhizal field grown garlic at different soil phosphorus levels. *J. Plant Nutr.*, 25: 1175–84
- Kawai, Y., and Y. Yamamoto. 1986. Increase in the formation and nitrogen fixation of soybean nodules by vesicular -arbuscular mycorrhiza. *Plant Cell Physiol.* 27:399–405.
- Kaya, İ. and S. Yalçın, 1999. Baklagil tane yemleri ve ruminant rasyonlarında kullanılması. *Lal. Hay. Araş. Enst. Derg.*, 39: 101–114.

- Kennedy, I. R. , Choudhury A.T.M.A., Kecskés M.L. 2004. Non-symbiotic bacterial diazotrophs in crop-farming systems: can their potential for plant growth promotion be better exploited? *Soil Biology an Biochemistry*, 36:8 : 1229- 1224.
- Khalequzzaman, K. M. and I. Hossain 2008. Efficacy of *Rhizobium* Strains and Biofertilizers for controlling foot and root rot and increasing green pod yield of bush bean. *Bangladesh J. Agril. Res.* 33(3) : 617-622.
- Khalil , I.A. and F.R. Durani. 1989. Nutritional evaluation of tropical legume and cereal forages grown in Pakistan, *Tropical Agriculture (Trinidad)*.67: 313–316.
- Khalil, S. K., M. S. Afridi and M. Iqbal. 1989. Response of monocultured and intercropped Maize and Mungbean to various levels of NPK. *Pakistan J. Agric. Res.*, 10: 23–9.
- Khalil, S., T. E. Loynachan and M. A. Tabatabai .1994. Mycorrhizal dependency and nutrient uptake by improved and unimproved corn and soybean cultivars. *Agronomy J.*, 86(6): 949-958.
- Khaliq, A., M. Arshad. A. Zahir and M. Khalid. 1997. Effect of Vesicular- Arbuscular. Mycorrhizal (VAM) inoculation and phosphorus application on maize seedling. *Sarhad J. Agric.*, 13 (5): 481.
- Khan, A. 2005. Role of soil microbes in the rhizospheres of plants growing on trace metal contaminated soils in phytoremediation. *J Trace Elem Med Biol.*, 18:355–364.
- Khan, H., F. Ahmad. S. Q. Ahmad, M. Sherin and A. Bari. 2006. Effect of phosphorus fertilizer on seed yield of lentil. *Sarhad J. Agriculture*. 22: 433-436.
- Khan, I. A. N., S. N. Ayub, S. M. Mirza, Nizam And M. Azam. 2008. Synergistic Effect Of Dual Inoculation (Vesicular-Arbuscular Mycorrhizae) on the growth and nutrients uptake of *Medicago sativa*. *Pak. J. Bot.*, 40(2): 939-945.
- Khan, M. R. and K. Kounsar. 2000. Effect of seed treatment with certain bacteria and fungi on the growth of mungbean and reproduction of *Meloidogyne incognita*. *Nematologia Mediterranea*, 28: 221-226.
- Khan, M. S. S., A. Latif, M. Rafique, T. Sajjad and L. Perveen. 2005. Effect of seed inoculation and phosphorus fertilizer on yield of chickpea in semi-arid areas of NWFP.

- Khaosaad, T., J. M. G. Garrido, S. Steinkellner and H. Vierheilig. 2007. Take-all disease is systemically reduced in roots of mycorrhizal barley plants. *Soil Biol. Biochem.*, 39: 727–34.
- Klironomos, J. N. and M. M. Hart. 2002. Colonization of roots by arbuscular mycorrhizal fungi using different sources of inoculum. *Mycorrhiza* 12: 181–184.
- Klironomos, J. N., 2000. Host-specificity and functional diversity among arbuscular mycorrhizal fungi. In: Bell, C.R., Brylinsky, M., Johnson-Green, P. (Eds.), Microbial biosystems: new frontiers. Proceedings of the 8th international symposium on microbial ecology. *Atlantic Canada Society for Microbial Ecology*, 845–851.
- Köhler, J., F. Caravaca and A. Roldán. 2009. Effect of drought on the stability of rhizosphere soil aggregates of *Lactuca sativa* grown in a degraded soil inoculated with PGPR and AM fungi. *Appl Soil Ecol.*, 42: 160–165.
- Köhler, J., F. Caravaca, L. Carrasco and A. Roldán. 2006. Contribution of *Pseudomonas mendocina* and *Glomus intraradices* to aggregate stabilization and promotion of biological fertility in rhizosphere soil of lettuce plants under field conditions. *Soil Use Manage* 22:298–304.
- Koide, R. T. 1991. Nutrient supply, nutrient demand and plant response to mycorrhizal infection. *New Phytologist*, 117, 365–386.
- Koide, R. T. and M. Li. 1990. On host regulation of the vesicular-arbuscular mycorrhizal symbiosis. *New Phytologist*, 114:59–65.
- Kormanik, P.P. 1982. Quantification of VAM in plant roots. Ed. *Methods and Principles of mycorrhizal research*. *Ann. Phytol. Soc.*, 37–45.
- Kottke, I. and F. Martin. 1994. Demonstration of aluminium polyphosphonate of *Laccaria amethystea* (Bolt-ex Hooker) Murr. by means of electron energy loss microscopy. *J. Microscopy*, 174: 225–232.
- Krishna Reddy, S. V. and I. P. S. Ahlawat. 2008. Growth and Yield Response of Lentil Cultivars to Phosphorus, Zinc and Biofertilizers. *J. Agronomy and Crop Science*, 177: 49–59.

- Kumar, N. and R. Chandra. 2003. *Rhizobium* and VA mycorrhizal inoculation effect on mungbean (*Vigna radiata*) with varying phosphorus levels. Karnal, India: Agricultural Research Communication Centre. *Legume-Research*, 26(4): 284-287.
- Kumar, R., B. L. Jalali and H. Chand. 2004. Effect of different VAM fungi on nodulation, nitrogenase activity and rhizosphere microflora of chickpea. Karnal, India: Agricultural Research Communication Centre. *Legume-Research*, 27(1): 50-53.
- Kumutha, K., J. Sempavalan and P. Santhonakrishnan. 2004. Effect of insoluble phosphate and dual inoculation on soybean. In: Biofertilizer technology Eds. S. Kannaiyan, K. Kumar and K. Govindaraj and scientific Publishers (India) Jodhpur, 354-358.
- Kushwaha, H. S. 2007. Response of chickpea to biofertilizers, nitrogen and phosphorus fertilization under rainfed environment. *Journal of Food Legumes*, 20(2): 179-181
- Kytöviita, M. M. 2005. Asymmetric symbiont adaptation to Arctic conditions could explain why high Arctic plants are non-mycorrhizal. *FEMS Microbiology Ecology*, 53(1): 27-32
- Levy**, A., B. J. Chang, L. K. Abbott, J. Kuo, G. Harnett and T. J. J. Inglis. 2003. Invasion of spores of the arbuscular mycorrhizal fungus *Gigaspora decipiens* by *Burkholderia* spp. *Appl Environ Microbiol.*, 69:6250–6256.
- Linderman, R. G. 2000. Effects of mycorrhizas on plant tolerance to diseases. In: Kapulnik Y, Douds DDJ (eds) *Arbuscular mycorrhizas: Physiology and function*. Kluwer Academic Publishers, Dordrecht: 345–365.
- Linderman, R. G. and E. A. Davis. 2004. Varied response of marigold (*Tagetes* spp.) genotypes to inoculation with different arbuscular mycorrhizal fungi. *Sci. Hort.*, 99: 67–78.
- Little, L. R. and M. A. Maun. 1996. The ammophila problem revisited: A role for mycorrhizal fungi. *J. of Eco.*, 84: 1-7.
- Liu, A., C Hamel, A. Elmi, C. Costa, B. Ma and D. L. Smith. 2002. Concentrations of K, Ca and Mg in maize colonised by arbuscular mycorrhizal fungi under field conditions. *Can. J. Soil Sci.*, 82(3): 271-278.
- Ludwig, and J. Muller. 2000. Indole-3-butyric acid in plant growth and development. *Plant Growth Regul* 32:219–230.

- Lukiwati, D. R. and R. D. M. Simanungkalit. 2002. Dry matter yield, N and P uptake of soybean with *Glomus manihotis* and *Bradyrhizobium japonicum*. In timetable of international Meeting on direct application of phosphorus rock and related technology – latest developments and practical experiences. International fertilizer development center muscle shoals (IFDC) USA Kuala Lumpur, Malaysia. 16-20.
- Lukiwati, D. R., S. Hardjosoewignjo, Y. Fakuara, I. Anas, T. R. Wiradarya and A. Rambe. 1997a. Nutrient uptake improvement of Centro and puero by rock phosphate fertilization and VAM inoculation in latosolic soil, 152-155.
- Lukiwati, D. R., S. Hardjosoewignjo, Y. Fakuara, I. Anas, T. R. Wiradarya and A. Rambe. 1997b. Improvement of phosphorus uptake of forages legumes by rock phosphate fertilization and vesicular-arbuscular mycorrhiza inoculation. In T. Ando, K. Fujita, T. Mae, H. Matsumoto, S. Mori and J. Sekiya (eds.). Proc. Of the XII International Plant Nutrition Colloquium. Tokyo, 13-19. Kluwer Academic Publishers. London.
- Mahboob, A.; Tahir, M.J.; Javed, A.A.; Mehmood, T. 2003. Agronomic traits of mungbean and subsequent rice crop as affected by seed inoculation and different fertilizer level. *Asian Journal of Plant Sciences* (Pakistan) Collativ. 2(3): 350-353.
- Maherali, H., Klironomos, J., 2007. Influence of phylogeny on fungal community assembly and ecosystem functioning. *Science* 316, 1746–1748.
- Mamatha, G., D.J. Bagyaraj, and S. Jaganath. 2002. Inoculation of field established mulberry and papaya with VAM fungi and mycorrhiza helper bacterium. *Mycorrhiza*, 12: 313-316.
- Manke N. M., Potdukhe S. R., Bramhankar S. B., Padghan P. R. 2008. Effect of rhizobium and VAM on growth parameters and yield of mungbean. *Journal of Plant Disease Sciences*, 3,(2).
- Manske, G. G. B. 1990. Genetical analysis of efficiency of VAM with spring wheat. *Agriculture Ecosystem*. 29(1-4): 273-280.
- Martins, L. M. V., G. R. Xavier, F. W. Rangel, J. R. A. Ribeiro, M. C. P. Neices, L. B. Morgado and N. G. Rumganek, 2003. Contribution of biological nitrogen fixation to cowpea, a strategy for improving grain yield in the semi-arid region of Brazil. *Biol. Fertil. Soils*, 38: 333-339.

- Marulanda A, Barea JM, Azcon R .2006. An indigenous drought tolerant strain of *Glomus intraradices* associated with a native bacterium improves water transport and root development in *Retama sphaerocarpa*. *Microb Ecol* 52:670–678.
- Mathur, N. and A. Vyas. 2000. Influence of arbuscular mycorrhizae on biomass production, nutrient uptake and physiological changes in *Ziziphus mauritiana* Lam. under water stress. *J. Arid Environ.*, 45:191-195.
- Maya, Ca Roopa. Ba, H. K. Makarib, and Nagaraj. K.2010. The synergistic effect of VAM Fungi with *Rhizobium* on the growth and yield Of *Cicer arietinum*. *L. International Interdisciplinary Research Journal*, {Bi-Monthly}, 2(1).
- Mayra, E. Gaito, Peter S. Curtis, Teis N. Mikkelsen and I. Jaksen. 2000. Atmospheric CO₂ and mycorrhiza effects on biomass allocation and nutrient uptake of nodulated Pea plants. *Journal of Experimental Botany*, 51 (352) 1931-1938.
- McGonigle, T P. K Yano, T Shinhama.2003. Mycorrhizal phosphorus enhancement of plants in undisturbed soil differs from phosphorus uptake stimulation by arbuscular mycorrhizae over non-mycorrhizal controls. *Biology and Fertility of Soils*, 37(5), Publisher: Springer , 268-273.
- Megan H. Ryan and Mark Tibbett.2008. The Role of Arbuscular Mycorrhizas in Organic Farming. *Organic Crop Production – Ambitions and Limitations* , 189-229, -6_10.
- Meghvansi, M. K. and S. K. Mahna. 2008. Evaluating the symbiotic potential of *Glomus intraradices* and *Bradyrhizobium japonicum* in vertisol with two soybean cultivars. *American-Eurasian Journal of Agronomy*, 2 (1): 21-25.
- Menge, J. A., D. Steirle, A. D. J. Bagy, E. L. V. Johnson and R. T. Leonard. 1978. Phosphorus concentrations in plants responsible for inhibition of mycorrhizal infection. *New Phytologist* 80:575-578.
- Meshram,-A-T; Jadhav,-A-C; Konde,-B-K; Wani,-P-.2000. Effect of VAM fungi and P-sources on nutrient uptake and yield of chickpea. *Journal-of-Maharashtra-Agricultural-Universities*. 24(3): 340-341.
- Miranda, D., J. C. C. Harris, P. J. and A. Wild. 1989. Effects of soil and plant phosphorus concentrations on vesicular-arbuscular mycorrhizae in sorghum plants. *New Phytologist*, 112:405-410.

- Miransari M, Smith D.L .2008. Using signal molecule genistein to alleviate the stress of suboptimal root zone temperature on soybean–*Bradyrhizobium* symbiosis under different soil textures. *J Plant Interact* 3:287–295.
- Miransari, M .2010b. Biological fertilization. In: Mendez-Villas A (ed) Current research, technology and education topics in applied microbiology and microbial biotechnology. Badajoz, Spain, in press
- Miransari, M. Mackenzie A. F. 2010c. Development of a soil N test for fertilizer requirements for wheat. *J. Plant. Nutr*, in press
- Miransari, M .2010a. Contribution of arbuscular mycorrhizal symbiosis to plant growth under different types of soil stresses. Review article. *Plant Biol* 12:563–569.
- Miransari, M, Smith D.L .2007. Overcoming the stressful effects of salinity and acidity on soybean [*Glycine max* (L.) Merr.] nodulation and yields using signal molecule genistein under field conditions. *J Plant Nutr* 30:1967–1992.
- Mishra, A. K. Parsad and Geeta. Rai. 2010. Effect of biofertilizer inoculation on growth and yield of dwarf field pea (*Pisum sativum* L.) in conjunction with different doses of chemical fertilizers. *Journal of Agronomy*, 9(4): 163-168.
- Moran, N. A, Wernegreen J. J .2000. Lifestyle evolution in symbiotic bacteria: insights from genomics. *Tree*, 15:321–326.
- Morin, C., J. Samson and M. Dessuresutt.1999. Protection for black spruce seedlings against *Cylindrocladium* root rot with ectomycorrhizal fungi. *Can.J. Bot.*, 77; 169-174.
- Morshed, R. M, M. M Rahman, M. A., Rahman.2008. Growth and Yield of Soybean (*Glycine max* L.) as Influenced by Phosphorus. *Bangladesh J. Sci. Ind. Res.* 43(3), 359-368.
- Mortimer, P. E., M. A. Pérez-Fernández and A. J. Valentine. 2008. The role of arbuscular mycorrhizal colonization in the carbon and nutrient economy of the tripartite symbiosis with nodulated *Phaseolus vulgaris* . *Soil Biology and Biochemistry*, 40 (5): 1019-1027.
- Motosugi H, Yamamoto Y, Naruo T, Kitabayashi H and Ishii T. 2002. Comparison of the growth and leaf mineral concentrations between three grapevine rootstocks and their

- corresponding tetraploids inoculated with an arbuscular mycorrhizal fungus *Gigaspora margarita*. *Vitis* 41(1): 21–25.
- Muhammad, D.; Gurmani, A.H.; Khan, M. 2004. Effect of phosphorus and Rhizobium inoculation on the yield and yield components of mungbean under the rainfed conditions of D.I. Khan [Pakistan]. *TiSarhad Journal of Agriculture (Pakistan)*, Collativ. 20(4) : 575-582.
- Muhammad, H., S. Hussain Shah & M. S. Nazir. 2003. Qualitative response of three lentil (*lens culinaris medic*) cultivars to phosphorus application. *Pak. J. Agri. Sci.*, 40 :(1-2).
- Muhammad, S. Anjum, Zammurad Iqbal Ahmed and Ch. A. Rauf. 2006. effect of *rhizobium* inoculation and nitrogen fertilizer on yield and yield components of mungbean. *International Journal Of Agriculture & Biology* . 08–2–238–240.
- Mukherjee, -P-K; Rai, -R-K. 2000. Effect of vesicular arbuscular mycorrhizae and phosphate-solubilizing bacteria on growth, yield and phosphorus uptake by wheat (*Triticum aestivum*) and chickpea (*Cicer arietinum* L.). *Indian-Journal-of-Agronomy*. 45(3): 602-607.
- Murat, E., S. Demir, E. O. S. Tufenkei, F. Oguz and A. Akkopru. 2011. Effects of Rhizobium, arbuscular mycorrhiza and whey applications on some properties in chickpea (*Cicer arietinum* L.) under irrigated and rainfed conditions 1—Yield, yield components, nodulation and AMF colonization. *Field Crops Research*, 122 (1): 14-24.
- Murthy, K. S. R. 2011. Nutritional potential and biochemical compounds in *Cajanus albicans* (wight & arn) van der maesan for food and agriculture. *Journal of Agricultural Technology.*, 7(1): 161-171.
- Muthukumar, T. and K. Udaiyan, 2000. Arbuscular mycorrhizas of plants growing in the Western Ghats region, southern India. *Mycorrhiza*, 9: 297–313.
- Mytton, L. R., and Livesey, C. J. 1983. Specific and general effectiveness of *Rhizobium trifoli* populations from different agricultural locations. *Plant Soil*. 73 : 299- 305.
- Naher, S. 2000. Comparative performance of bio-fertilizer and chemical fertilizer on the yield and yield contributing characters of mungbean. M.S. Thesis, Dept of Agron., Bangladesh Agril. Univ., *Mymensingh*, Bangladesh. 1-62.

- Nasim, G., M. Shaheen, R. Bajwa and R. Zahoor. 1996. Effect of age of host on the development of vesicular arbuscular mycorrhiza in peanut. *Pak. J. Phytopathoi.*, 8 (1): 28-36.
- Nazir, H., B. Hassan, R. Habib, L. Chand, A. Ali and A. Hussain. 2011. Response of biofertilizers on growth and yield attributes of blackgram . *International Journal of Current Research*. 2 (1): 148-150.
- Nazir, R., J. Warmink, H. Boersma and J. van Elsas. 2010. Mechanisms that promote bacterial fitness in fungal-affected soil microhabitats. *FEMS Microbiol Ecol.*, 71: 169-185.
- Nazmun A, M Rokonzaman, M. N Hasan. 2009. Effect of *Brady rhizobium* and *zotobacter* on growth and yield of mungbean varieties *J. Bangladesh Agril. Univ.* 7(1): 7-13.
- Neveen. B., Talaat, M. Amany M. Abdallah. 2008. Response of Faba Bean (*Vicia faba* L.) to Dual Inoculation with *Rhizobium* and VA Mycorrhiza under Different Levels of N and P Fertilization. *Journal of Applied Sciences Research*, 4(9): 1092-1102.
- Newsham, K. K., A. H. Fitter, and A. R. Watkinson. 1995. Multi-functionality and biodiversity in arbuscular mycorrhizas. *Tree*. 10:407-411.
- Niranjan, R., R. Shukla, R. Pareek and V. M. Rao. 2002. Dual inoculation effect of *Rhizobium* (cow pea miscellany) and VAM fungi on growth, nodulation and nitrogen fixation in *Prosopis cineraria*. Bharatpur, India *Phytological Society. Journal-of-Phytological-Research*, 15(2): 149-153.
- Nishita, G. and N. C. Joshi. 2010. Growth and yield response of chick pea (*Cicer arietinum*) to seed inoculation with *Rhizobium* sp. *Nature and Science*, 8(9).
- O'Connor, P. J., S. E. Smith and A. F. Smith. 2002. Arbuscular mycorrhizas influence plant diversity and community structure in a semiarid herbland. *New Phytol.*, 154: 209–18.
- O'Kane., F. E. O'Kane, R. P. Happe, J. M. Vereijken, H. Gruppen and M. A. J. S. van Boekel. 2004. Characterization of Pea Vicilin: 1. Denoting convicilin as the α -subunit of the Pisum vicilin family, *J. Agricultural and Food Chemistry*, 3141–3148.

- Oehl, F., E. Sieverding, K. Ineichen, P. Mäder, T. Boller and A. Wiemken. 2003. Impact of land use intensity on the species diversity of arbuscular mycorrhizal fungi in agroecosystems of central Europe. *Appl Environ Microbiol.* 69: 2816–2824.
- Oehl, F., E. Sieverding, K. Ineichen, E. A. Ris, T. Boller, and A. Wiemken. 2005. Community structure of arbuscular mycorrhizal fungi at different soil depths in extensively and intensively managed agroecosystems. *New Phytol*, 165: 273-283.
- Olivera, M., N. Tejera, C. Iribarne, A. Ocana and C. Liuch. 2004. Growth, nitrogen fixation and ammonium assimilation in common bean (*Phaseolus vulgaris*) effect of phosphorus. *Physiol. Plant.*, 121: 498–505.
- Olsen, S. R. and L. E. Sommers. 1982. Potassium In: A.L. Page, R.H. Miller and D.R. Keeney (eds.). Method of Soil Analysis. Analysis. Part 2 Agronomy 9. *American Society of Agronomy*, Madison, W.L., 403-427.
- Omomowo, I. O. 2006. The effect of inoculation of *Bradyrhizobium japonicum* and *Glomus mosseae* on seed weight and nutrient composition of soybean and cowpea. M.Sc dissertation, University of Agriculture Abeokuta, : 109.
- Omomowo, I. O., I. O. Ola, A. K. Akintokun, M. O. Bankole and O. A. Babalola. 2009. Direct and residual influence of inoculation with *Glomus mosseae* and *Bradyrhizobium japonicum* on proximate and nutrient element content of cowpea seeds. *American-Eurasian J. Sustainable Agriculture*. 3(3): 435-441.
- Omsub, N. 2009. Role of VA Mycorrhizal in the Phosphorus Nutrition of Economic Leguminous Crops in Thailand. (USAID – PSTC). (FAO) work plan in 2004 to 2009. This Biofertilizer Newsletter is issued by the Japan Atomic Industrial Forum Inc. (JAIF) under the contract of the Ministry of Education, Culture, Sports, Science and Technology.
- Ortas, I., Z. Kaya and I. Çakmak. 2001. Influence of VA-Mycorrhiza Inoculation on Growth of Maize and Green Pepper Plants in Phosphorus and Zinc Deficient Soils. In plant Nutrition- Food security and sustainability of agro-ecosystems: 632-633.
- Osundina, M. A., J. K. Oloke, O. O. Fawole and M. O. Liasu. 1998. Diversity of organism. Y-Books. Ibadan (Lautech Book Series): 5-4.
- Özdemir, S. 2002. *Edible Legumes*, 71–90. Hasat Publishing, Istanbul, Turkey.

- Ozturk, A., O. Caglar and F. Sahin. 2003. Yield response of wheat and barley to inoculation plant growth promoting rhizobacteria at various levels of nitrogen fertilization. *Journal of Plant Nutrition and Soil Science*, 166:1–5.
- Palta, C., U. Karadavut, O. Okur and Z. Kavurmac. 2010. Relationships between grain yield, organic matter digestibility, crude protein, ash concentration and water soluble carbohydrates in non-irrigated cereals which are used as animal feeds. *J. Anim. Vet. Adv.*, 9: 205–209.
- Pande, M. and J. F. Tarafdar. 2004. Arbuscular Mycorrhizal fungal diversity in Neem based Agroforestry Systems in Rajistan. *Applied Soil Ecology*, 26: 233–241.
- Paola, B. and I. A. Anca. 2009. Plants, Mycorrhizal Fungi, and Bacteria: A Network of Interactions. *Annual Review of Microbiology*. 63: 363–383.
- Parke, J. L. and S. A. Kaeppler. 2000. Effects of genetic differences among crop species and cultivars upon the arbuscular mycorrhizal symbiosis. In: Kapulnik, Y. and D.D. Douds (eds.), *Arbuscular Mycorrhizas: Physiology and Function*, 131–46.
- Parniske, M. 2000. Intracellular accommodation of microbes by plants: a common developmental program for symbiosis and disease. *Curr. Opin. Plant Biol.*, 3: 320–8.
- Pasqualini, D., Uhlman, A. and Sturmer, S.L. 2007. Arbuscular mycorrhizal fungal communities influence growth and phosphorus concentration of woody plants species from Atlantic rain forest in South Brazil. *Forest Ecology and Management* 245 :148–155.
- Paszkowski, U., S. Kroken, C. Roux, S. P. Briggs. 2002. Rice phosphate transporters include an evolutionarily divergent gene specifically activated in arbuscular mycorrhizal symbiosis. *Proceedings of the National Academy of Sciences of the United States of America* 99: 13324–13329.
- Patel, D., M. K. Arvadia and A. J. Patel. 2007. Effect of integrated nutrient management on growth, yield and nutrient uptake by chickpea on Vertisol of South Gujarat. *Journal-of-Food-Legumes*, 20(1): 113–114.
- Persello-Cartieaux, F., L. Nussaume and C. Robaglia. 2003. Tales from the underground: molecular plant-rhizobacteria interactions. *Plant Cell Environ.* 26: 189–199.

- Perveen, S., M. S. Khan and A. Zaidi. 2002. Effect of rhizospheric microorganisms on growth and yield of greengram (*Phaseolus radiatus*). *Ind.J. Agric.Sci.* 72: 421-423.
- Philanto, A. and H. Korhonen. 2003. Bioactive peptides and proteins, *Advances in Food and Nutrition Research*, 47: 175–181.
- Phillips, J. M. and D. S. Hayman. 1970. Improved procedures for clearing roots and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid assessment of infection. *Transaction British Mycological Society*, 55: 158-161.
- Pir, F. A., F. A. Nehvi, Abu-Manzar, S. A. Dar, B. A. Allai. 2009. Integrated phosphorus management in mungbean in Kashmir valley. *Trends-in-Biosciences*. 2(2): 25-26.
- Plenchette, C. A., A. Fortin and N. Forlan. 1983. Growth response of several plant species to mycorrhiza in a soil of moderate P-fertility. I. Mycorrhizae under field conditions. *Plant Soil*. 70:199-203.
- Plenchette, C., C. Clermont-Dauphin, J. M. Meynard and J. A. Fortin. 2005. Managing arbuscular mycorrhizal fungi in cropping systems. *Canadian J. Plant Sci.*, 85: 31-40.
- Pongrac, P., K. V. Mikus, P. Kump, M. Nečemer, R. Tolra, C. Poschenrieder, J. Barcelo and M. Regvar, 2007. Changes in elemental uptake and arbuscular mycorrhizal colonization during the life cycle of *Thlaspi praecox* Wulfen. *Chemosphere J.*, 69: in press.
- Poonam-S., Sekhon,-H-S; Veena-Khanna; Guriqbal-Singh. 2007. Biological nitrogen fixation in mungbean: facts and findings. *Acta-Horticulturae*, (752): 597-601
- Potdukhe, S. R. and D. D. Guldekar. 2003. Studies on synergistic effect of dual inoculation of Rhizobium, BSP and antagonistic bacteria on nodulation and grain yield of mungbean. *Annals-of-Plant-Physiology*. 17(1): 78-80.
- Powell, J. R., J. L. Parrent, M. M. Hart, J. N. Klironomos, M. C. Rillig, H. Maherali. 2009. Phylogenetic trait conservatism and the evolution of functional tradeoffs in arbuscular Mycorrhizal fungi. *Proceedings of the Royal Society B*. 276: 4237–4245.
- Pozo, M. and C. A. Aguilar. 2007. Unraveling mycorrhiza-induced resistance. *Curr Opin Plant Biol*. 10: 393–398.

- Pragatheswari, D., A. Manjunath, M. Madhaiyan and K. Kumutha. 2004. Soil solution phosphorus status and mycorrhizal inoculation efficiency of selected tropical grain legumes in an alfisol. Jodhpur, India: Scientific Publishers (India). Biofertilizers-technology- for-rice- based- cropping- system; 334-341.
- Price, N., R. Roncadori and R. Hussey. 1989. Turgor solute import and growth in maize roots treated with galactose. *New Phytologist*, 31, 1095–1103.
- Rabbani, N., A. Javaid and R. Bajwa, 2002. Genotype dependant variation in VAM colonization in rice. *Pakistan J. Phytopathol.*, 13: 39–44.
- Rabie, G.H., 1998. Induction of fungal disease resistance in *Vicia faba* by dual inoculation with *Rhizobium leguminosarum* and vesicular-arbuscular mycorrhizal fungi. *Mycopathologia*, 141: 159-166.
- Raghwendra-S., P. Kedar. 2008. Effect of vermicompost, *Rhizobium* and DAP on growth, yield and nutrient uptake by chickpea. *Journal of Food Legumes*. 21(2): 112-114.
- Rahman, M. K., S. M. Kabir, G. M. Mohsin, M. D. Alam and R. Mandal. 2008. Effects of inoculation with arbuscular-mycorrhizal fungi and phosphorus on growth, yield and nutrient uptake of mungbean grown in sterile and non-sterile soil. *Journal-of-Phytopathological-Research*, 21(2): 247-251.
- Rajaram, N. and K. Janardhanan. 1990. Chemical composition and nutritional evaluation of certain under-explored *Vigna* sp. *Food Science and Nutrition* 42: 213- 221.
- Rajasekaran, S. and S. M. Nagarajan. 2005. Effect of dual inoculation (AM fungi and (*Rhizobium*) on chlorophyll content of *Vigna unguiculata* (L.) Walp. var. Pusa 151. New Delhi, India: Tata Energy Research Institute. *Mycorrhiza*, 17(1): 10-11.
- Ramakrishna, A., S. P. Wani, C. S. Rao and U. S. Reddy. 2005. Increased chickpea yield and economic benefits by improved crop production technology in rainfed areas of Kurnool District of Andhra Pradesh, India. *Journal-of-SAT-Agricultural-Research*, 1(1): 1-3
- Ramasamy, M., K. Srinivasan and N. Sankaran. 2000. Effect of 'P' mobilizers and different levels of phosphorus on growth and yield of Co.1 soybean. *Madras Agricultural Journal.*, 87(10/12): 674-675.

- Rao., Rao, R., A. Costa, R. R. D. Croy, D. Boulter and J. A. Gatehouse. 1989. Variation in polypeptides of the major albumin protein of pea (*Pisum sativum* L.): Inheritance and molecular analysis, *Molecular General Genetics*, 219 : 277–281.
- Ray J. G. and N. Valsalakumar. 2010. Arbuscular Mycorrhizal fungi and *rhizobium* under varied doses of NPK on green gram . *екологія та ноосферологія*. 21(3): 473.
- Ray, J. G. and N. Valsalakumar, 2010. Arbuscular mycorrhizal fungi and *rhizobium* under varied doses of NPK on green gram. *issn 1726-1112. екологія та ноосферологія*. 21,3–4.
- Regitano, A. M. A., S. M. Carpi, G. M. Camara, C. E. Baggio and E. A. Marcos. 1995. Effects of nitrogen sources on soybean (*Glycine max*) oil characteristics and seed storeability. *Tropical Sci.*, 35, 135–140.
- Reynolds, H. L., A. Packer, J. D. Bever and K. Clay. 2003. Grassroots ecology: plant–microbe–soil interactions as drivers of plant community structure and dynamics. *Ecology*. 84: 2281–2291.
- Richardson, A. E., 2001. Prospects for using soil microorganisms to improve the acquisition of phosphorus by plants. *Aust. J. Plant Physiol.* 28, 897–906.
- van Straaten, P., 2002. Rocks for crops: agrominerals of sub-Saharan Africa. ICRAF, Nairobi.
- Richardson, A., J. M. Barea, A. McNeill, C. P. Combaret. 2009. Acquisition of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. *Plant Soil*, 321: 305–339.
- Rillig, M. C. and D. L. Mummey. 2006. Mycorrhizas and soil structure. *New Phytol.*, 171: 41–53.
- Rillig, M. C., E. R. Lutgen, P. W. Ramsey, J. N. Klironomos and J. E. Gannon. 2005. Microbiota accompanying different arbuscular mycorrhizal fungal isolates influence soil aggregation. *Pedobiology*, 49: 251–259.
- Rodelas, B., J. G. Lopez, C. Pozo, V. Salmeron and M. V. Martinez-Toledo. 1999. Response of Faba bean (*Vicia faba* L.) to combined inoculation with *Azotobacter* and *Rhizobium leguminosarum* bv. *viceae*. *App Soil Ecol.* 12: 51–59.
- Rodriguez, H. and R. Fraga. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnology Advances*, 17 (Suppl 4-5): 319–339.

- Rohyadi, A., F. A. Smith, R. S. Murray and S. E. Smith. 2004. Effects of pH on mycorrhizal colonization and nutrient uptake in cowpea under conditions that minimize confounding effects of elevated available aluminium. Dordrecht, Netherlands: Kluwer Academic Publishers. *Plant and Soil*; 260(1/2): 283-290.
- Rokhzadi, A., V. Toashih. 1991. Nutrient uptake and yield of chickpea (*Cicer arietinum* L.) inoculated with plant growth promoting rhizobacteria. *AJCS.*, 5(1):44-48
- Rotor, A. V and P. C. Delima. 2010. Mycorrhizal association, fertilization and biocide application on the efficacy of bion on corn (*zea mays l.*) growth and productivity. *International Scientific Research Journal*, 2 (3): 269-271.
- Rudresh, D. L., M. K. Shivaprakash, R. D. Prasad. 2005. Effect of combined application of Rhizobium, phosphate solubilizing bacterium and Trichoderma spp. on growth, nutrient uptake and yield of chickpea (*Cicer aritenium* L.). *Applied-Soil-Ecology.*, 28(2): 139-146.
- Ruiz-Lozano, J. M. 2006. Physiological and molecular aspects of osmotic stress alleviation in arbuscular mycorrhizal plants. In: *Handbook of Microbial Biofertilizers*. (Ed.): Mahendra Rai, Haworth press, New York, 283-303.
- Ruiz-Lozano, J. M. and P. Bonfante. 2000. Intracellular Burkholderia of the Arbuscular Mycorrhizal fungus Gigaspora margarita possesses the vac B gene, which is involved in host cell colonization by bacteria. *Microb Ecol.*, 39: 137–144.
- Sabannavar, S. J. and H. C. Lakshman. 2009. Effect of Rock Phosphate Solubilization Using Mycorrhizal Fungi and Phosphobacteria on Two High Yielding Varieties of *Sesamum indicum* L. *World Journal of Agricultural Sciences* , 5 (4): 470-479,
- Saif, S. R. and A. G. Khan. 1975. The influence of season and stage of development of plants on *Endogone*, mycorrhiza of field grown wheat. *Canadian Jour. Microbios.*, 21: 1020- 1024.
- Saleh M. Saleh Al-Garni. 2005. Increased heavy metal tolerance of cowpea plants by dual inoculation of an arbuscular mycorrhizal fungi and nitrogen-fixer *Rhizobium* bacterium. *African Journal of Biotechnology*, 5 (2), 133-142, 16
- Sammauria, R. and R. S. Yadav, Head and K. C. Nagar. 2009. Performance of cluster bean (*Cyamopsis tetragonoloba*) as influenced by nitrogen and phosphorus

- fertilization and biofertilizers in Western Rajasthan. *Indian J. Agronomy*, 54(3): 319-323.
- Sapatnekar, H. G., P. H. Rasal and P. Patil. 2002. Role of biofertilizers and P-sources in chickpea cultivation. *J. Maharashtra Agricultural Universities*, 27(2): 225-226.
- Sara, L., C. Ricalde, N. M. Montaña, I. R. Jaramillo, C. J. Gonzalez and S. S. Dhillion. 2009. Effect of Mycorrhizae on seedlings of six endemic *Mimosa* L. species (*Leguminosae-Mimosoideae*) from the semi-arid Tehuacán-Cuicatlán Valley, Mexico. *Biomedical and Life Sciences*. 67-78.
- SAS. 1998. Statistical Analysis Software, Version 6.12. SAS Institute, Cary, NC, USA.
- Satpal, S. K. K. Kapoor. 2000. Influence of inoculation of different vesicular arbuscular mycorrhizal fungi on growth and nutrient of mungbean and wheat. Manila, Philippines: Science and Technology Information Institute. *Philippine Journal of Science*, 129(1): 19-25.
- Satter, M. A., M. M. Hanaif, T. M. M. Mahmud and H. Azizah. 2006. Influence of Arbuscular Mycorrhiza and Phosphate rock on uptake of major nutrients by *Accia mangium* seedling on degraded soil. *Biology and fertility of soil*, 42(4): 345-349.
- Satyawati, S. S. Kashyap and P. Vasudevan. 2005. Effect of bioinoculants on biomass productivity under agroforestry systems. New Delhi, India: National Institute of Science Communication and Information Resources. *Indian Journal of Biotechnology*, 4(1): 156-160.
- Sayeed, M., Akhtar and A. Z. Siddiqui. 2007. Biocontrol of a root-rot disease complex of chickpea by *Glomus intraradices*, *Rhizobium* sp. and *Pseudomonas straita*. *Crop Protection*. 27, 3(5): 410-417.
- Schenck, N. C. and Y. Perez. 1990. Manual for the Identification of VAM Fungi. 3rd Ed.
- Scheublin, T. R., V. D. Heijden and G. A. Marcel. 2006. Arbuscular Mycorrhizal fungi colonize non fixing root nodules of several legume species. *New Phytologist*, 172: 732-738.
- Schubler, A., D. Schwarzott and C. Walker. 2001. A new fungal phylum, the *Glomeromycota*: phylogeny and evolution. *Mycol. Res.*, 105(12): 1413-1421.
- Sensoy, S., S. Demir, O. Turkmen, C. Erdinc and O. B. Savur. 2007. Responses of some different pepper (*Capsicum annuum* L.) genotypes to inoculation with two different arbuscular mycorrhizal fungi. *Sci. Hort.*, 113: 92-5.

- Shakya, M. S., M. M. Patel and V. B. Singh. 2008. Knowledge level of chickpea growers about chickpea production technology. *Indian Res. J. Ext. Edu.*, 8: 65-68.
- Sharma, A. K. 2004. Biofertilizers for sustainable agriculture. 1st ed. Published by Agrobios (India). 201-209.
- Sharma, O. P. 2003. Textbook of Fungi. TaTa McGraw-Hill Publishing Company Limited. India. 312.
- Shehata, S. M., S. Heba, A. Azem, A. A. El-Yazied and A. M. El-Gizawy. 2010. Interactive effect of mineral nitrogen and biofertilization on the growth, chemical composition and yield of celeriac plant. *European Journal of Scientific Research*, 47(2): 248-255.
- Sheraz, M., S. G. I. Hassan, S. A. Samoon, H. A. Rather, Showkat A. Dar and B. 2010. Bio-Fertilizers In Organic Agriculture. *Journal of Phytology* .2(10): 42-54.
- Sher. S. Saini, S. S. Singh, B. P. 2004. Yield, quality, nutrient content and uptake in late sown chickpea (*Cicerarietinum* L.) as influenced by irrigation, sulphur and seed inoculation levels. *Haryana-Journal-of-Agronomy*, 20(1/2): 46-48.
- Sheteawi, S. A. and K. M. Tawfik. 2007. Interaction effect of some biofertilizers and irrigation water regime on mung bean (*Vigna radiata*) growth and yield. *J. Applied Sciences Research*, 3(3): 251-262.
- Shivakumar, B. G. and S. N. Sidramappa. 2004. Influence of sources and levels of phosphorus with and without phosphorus solubilizing bacteria (PSB) seed treatment on growth and yield of soybean. *Annals of Agricultural Research*, 25(2): 333-334.
- Shivakumar, B. G., S. S. Ballari and C. S. Saraf. 2004. Effect of sources and levels of phosphorus with and without seed inoculation on the performance of rain fed chickpea (*Cicerarietinum* L.). *Ann. Agric. Res. New Series*, 25(2): 320-326.
- Shuhe, W., W. Chang, W. Xiaojuan and J. Liang. 2008. Molecular Basics of tripartite symbiosis formed by rhizobia, arbuscular mycorrhizal (AM) fungi and legumes. *Chinese J. Applied & Environmental Biology*. 05-028.
- Sikes, B. A., K. Cottenie and J. N. Klironomos. 2009. Plant and fungal identity determines pathogen protection of plant roots by arbuscular mycorrhizas. *J. Ecology*. 97: 1274–1280.

- Silva, M. A., V. Neves and E. J. Lourenço. 2001. Protein fractions and major globulin from chickpea (*Cicer arietinum* L.), *Alimentos e Nutrição* 12: 131–149.
- Sindhu, S. S., S. K. Gupta, and K. R. Dadarwal. 1999. Antagonistic effect of *Pseudomonas* spp. on pathogenic fungi and enhancement of plant growth in green gram (*Vigna radiata*). *Biology and Fertility of Soils* 29: 62–68.
- Sindhu, S. S., S. Suneja A. K. Goel, N. Parmar and K. R. Dadarwal. 2002. Plant growth promoting effects of *Pseudomonas* sp. on coinoculation with *Mesorhizobium* sp. *cicer* strain under sterile and “wilt sick” soil conditions. *Applied Soil Ecology*, 19: 57–64.
- Singh, B. and R. G. Pareek. 2003. Effect of phosphorus and biofertilizers on growth and yield of mungbean. *Indian Journal of Pulses Research*, 16(1): 31-33.
- Singh, H. P. and T. A. Singh. 1993. Effect of VA Mycorrhizae in Chick Pea. *Mycorrhizae* 3: 37-39.
- Singh, K. K., C. Srinivasarao and M. Ali. 2005. Root growth, nodulation, grain yield, and phosphorus use efficiency of lentil as influenced by phosphorus, irrigation, and inoculation. *Communications in Soil Science and Plant Analysis.*, 36(13/14): 1919-1929.
- Singh, P. K. and A. K. Singh. 2010. Response of mungbean (*Vigna radiata* L. Wilczek) in relation to micronutrients content and yield as affected by sulfur and cobalt application. *Environment and Ecology*, 28(1B): 564-568.
- Singh, P.K. and S. Sahu. 2009. Effect of micro nutrients and biofertilizers on N, P, K and S content uptake and yield of chickpea crop. *Environment-and-Ecology*, 27(3): 1123-1126.
- Singh, R. 2003. Introduction to Biotechnology. Principles and Application. 1 st. Ed. Vol. 1. pp. 27.
- Singh, R. K. 2008. Influence of Biofertilizer, fertility level and weed management practice on weed growth and yield of late sown chickpea (*Cicer arietinum* L.). *Environment and Ecology*, 26(3A): 1306-1309.
- Singh, S. R., M. I. Bhat, J. A. Wani and G. R. Najar. 2009. Role of *Rhizobium* and VAM Fungi for Improvement in Fertility and Yield of Green Gram under Temperate Conditions. *Journal of the Indian Society of Soil Science*. 57(1).

- Singh, P.-K. S. Seema. 2009. Effect of micro nutrients and biofertilizers on N, P, K and S content uptake and yield of chickpea crop. *Environment and Ecology*, 27(3): 1123-1126.
- Smith, S. E. and D. J. Read. 1997. Mycorrhizal Symbiosis. Academic Press, London.
- Smith, S. E. and D. J. Read. 2008. Mycorrhizal symbiosis, 3rd ed. Academic Press, London, UK.
- Smith, S.E., E. Facelli, S. Pope and F. A. Smith. 2010. Plant performance in stressful environments: interpreting new and established knowledge of the roles of arbuscular mycorrhizas. *Plant and Soil*, 326: 3-20.
- Solaiman, A. R. M., Molla, M. N. and M. D. Hossain. 2006. Response of chickpea to dual inoculation with *Rhizobium* and Arbuscular Mycorrhiza, Nitrogen and Phosphorus. *Korean J. Crop Sci.*, 51(6): 527-533.
- Somers, E., J. Vanderleyden and M. Srinivasan. 2004. Rhizosphere bacterial signaling: A love parade beneath our feet. *Crit ev Microbiol*, 30: 205-240.
- Souchie, E. L., J. Orivaldo, O. J. Saggin-Junior, E. M. R. Silva, E. F. C. Campello, R. Azcon and J. M. Barea. 2006. Communities of P-solubilizing bacteria, fungi and arbuscular mycorrhizal fungi in grass pasture and secondary forest of Paraty, RJ-Brazil. *An. Acad. Bras. Cienc.*, 78: 183.
- Srivastava, R. P. and M. Ali. 2004. Nutritional quality of common pulses: Indian Institute of pulses Research, Kanpur, 14-22.
- Stacey, P., P. O. Kiely, R. Hackett, B. Rice and F. P. O. Mara. 2006. Changes in yield and composition of barley, wheat and Triticale grains harvested during advancing stages of ripening. *Irish J. Agric. Food Res.*, 45: 197–209.
- Stahl, P. D. and M. Christensen. 1982. Mycorrhizal fungi associated with *Bouteloua* and *Agropyron* in Wyoming Sagebrush grass. *Mycologia*, 74 (6): 87 885.
- Subba Roa, N. S. 1982. Advances in agricultural microbiology. *Oxford and IBM Pub.*, New Delhi pp. 296.
- Subba Roa, N. S. 2001a. An appraisal of biofertilizers in India. The biotechnology of biofertilizers (ed.) S.Kannaiyan, Narosa Pub. House, New Delhi (in press).

- Sundara, T. H., B. S. Vyakaranahal, M. Shekhargouda, S. D. Shashidhara and R. M. Hosamani. 2004. Influence of phosphorus and micronutrients on seed yield and quality of pea (*Pisum sativum* L.). *Seed Research*. 32(2): 214-216.
- Sutton, J. C. and G. L. Barro. 1972. Population dynamics of *Endogone* spores in soil. *Can. J. Bot.*, 50: 1909-1914.
- Swanson, B. G. 1990. Pea and lentil protein extraction and functionality, *Journal of the American Oil Chemists' Society*, 67: 276–280.
- Sylvia, D. M. 2003. Overview of mycorrhizal symbiosis. University of Florida. Taber.
- Taiwo, L. B. and A. A. Adgebite. 2001. Effect of arbuscular mycorrhizal and *bradyrhizobium* inoculation on growth, Nitrogen fixation and yield of promiscuously nodulating soybean (*Glycine max*), *Journal of Agricultural Research*, 2: 110-118.
- Takeda, N., C. Kistner, S. Kosuta, T. Winzer, A. Pitzschke, M. Groth, M. Sato, T. Kaneko, S. Tabata and M. Parniske. 2007. Proteases in plant root symbiosis. *Phytochemistry*, 68: 111–21.
- Talbot, J. M., S. D. Allison, and K. K. Treseder. 2008. Decomposers in disguise: mycorrhizal fungi as regulators of soil C dynamics in ecosystems under global change. *Funct. Ecol.*, 22: 955-963.
- Tarafdar, J. C. and Rao, A. V. 2001. Response of cluster bean to *Glomus mossea* and *Rhizobium* in an arid soil fertilized with nitrogen, phosphorus and farm yard manure. *Journal of the Indian Society of Soil Science*, 49:751-755.
- Thakur, A. K. and J. D. Panwar. 1995. Effect of *Rhizobium* VAM interactions on growth and yield of mungbean (*Vigna radiata* L.) under field conditions. *Indian J. Plant Path.*, . 38: 62-65.
- Thangadurai, D., M. B. Viswanathan and N. Ramesh. 2001. Nutritional potential of biochemical composition in *Galactia longifolia* Benth. (Fabaceae) *Nahrung/Food* 45:97-100.
- Tharanathan, R. N. and S. Mahadevamma. 2003. Grain legumes – A boon to human nutrition, *Trends in Food and Science Technology*, 14 :507–518.
- Thenua, O. V. S., Singh, S. P and B. G. Shivakumar. 2010. Productivity and economics of chickpea (*Cicer arietinum* L.) fodder sorghum (*Sorghum bicolor*) cropping system

- as influenced by P sources, bio-fertilizers and irrigation to chickpea. *Indian Journal of Agronomy*, 55(1): 22-27.
- Thomas R.L, Sheard R.W and Moyer J.R.1967. Comparison of conventional and automated procedures for N, P and K analysis of plant material using a single digestion. *Agron J.*, 59: 240-243.
- Toro, M., A. N. Azco, and J. M. Barea. 1997. Improvement of arbuscular mycorrhiza development by inoculation of soil with phosphate-solubilizing rhizobacteria to improve rock phosphate bioavailability (^{32}P) and nutrient cycling. *Appl. Environ. Microbiol.*, 63: 4408-4412.
- Trappe, J. M. 1982. Synoptic keys to the genera and species of zygomycetous mycorrhizal fungi. *Phytopathol.*, 72 (8): 1102-1107
- Tufenkci, S., F. Sonmez, and R. I. G. 2005. Effects of arbuscular mycorrhiza fungus inoculation and phosphorous and nitrogen fertilizations on some plant growth parameters and nutrient content of chickpea. *J. Biological Sci.* 5(6): 738-743.
- Tüzen, M. 2003. Determination of heavy metals in soil, mushroom and plant samples by atomic absorption spectrometry. *Microchemical Journal*, 74, 289–297.
- Ufuk, K. and Aşir G.2010.Relationships between chemical composition and seed yield of some lentil (*lens culinaris*) cultivars.*International Journal of Agriculture & Biology*, 12(4): 625–628.
- Valdenegro, M., J. M. Barea and R. Azcón.2001. Influence of arbuscular-mycorrhizal fungi, *Rhizobium meliloti* strains and PGPR inoculation on the growth of *Medicago arborea* used as model legume for re-vegetation and biological reactivation in a semi-arid Mediterranean area, *Plant Growth Regul.*, 34 : 233–240.
- Valsalakumar, J. G. Ray and V. P. Potty.2006. Arbuscular Mycorrhizal Fungi Associated with Green Gram in South India. *Agronomy Journal*, 99 (5):1260-1264.
- Valsalakumar, N., J. G. Ray and V. P. Potty.2007. Arbuscular Mycorrhizal fungi Associated with green gram in South India. *Agron. J.*, 99: 1260-1264.
- Van der Putten, W. H., 2003. Plant defense belowground and spatiotemporal processes in natural vegetation. *Ecology*, 84: 2269–2280.
- Van Wees S, Van der Ent S, Pieterse C .2008. Plant immune responses triggered by beneficial microbes. *Curr Opin Plant Biol.*,11:443–448.

- Vejsadova, H., Siblikova, D., Hrselova, H., Vancura, V., 1992. Effect of the VAM fungus *Glomus* sp. on the growth and yield of soybean inoculated with *Bradyrhizobium japonicum*. *Plant Soil*, 140(1), 121-125.
- Vejsadová, H., D. Siblíkova, M. Gryndler, T. Simon, and I. Miksik. 1993. Influence of inoculation with *Bradyrhizobium japonicum* and *Glomus claroideum* on seed yield of soybean under greenhouse and field conditions. *J. Plant Nutr.* 16:619–629.
- Venkatashwarlu, B. 2008a. Role of bio-fertilizers in organic farming: Organic farming in rain fed agriculture: Central institute for dry land agriculture, Hyderabad.: 85-95.
- Verma, L. K and R. P. Singh. 2008. Effect of phosphorus on nitrogen fixing potential of rhizobium and their response on yield of mung bean [*Vigna radiata* (L.)]. *Asian J. Soil Science*, 3(2): 310-312.
- Vessey, J. K., 2003. Plant growth promoting rhizobacteria as biofertilizers. *Plant Soil*, 255: 571-586.
- Vigo, C., J. R. Norman and J. E. Hooker. 2000. Bio control of the pathogen *Phytophthora parasitica* by arbuscular mycorrhizal fungi is a consequence of effects on infection loci. *Plant Pathology*, 49: 509–514.
- Vijla, K. and S. Jebaraj. 2008. Studies on the improvement of rhizobium-green gram (*Vigna mungo* L.) (Wilezek) symbiosis in low nutrient, acid stress soil. *Legume Research*, 31(2): 126-129.
- Vinicius Ide Franzini, Rosario Azcón, Fernanda Latanze Mendes and Ricardo Aroca. 2009. Interactions between *Glomus* species and *Rhizobium* strains affect the nutritional physiology of drought-stressed legume hosts. *Journal of Plant Physiology*, 167(8):614-619.
- Vishram-Ram; Yadav, -P-K; Dohare, -A-P-S; Lodhi, -M-D. 2007. Effect of biofertilizers and phosphorus levels on growth and yield of chickpea (*Cicer arietinum* L.) in rainfed area under bundelkhand conditions. *Plant-Archives*. 7(1): 237-239.
- Vogt, S. T. and W. Schliemann. 2003. Recent advances in betalain research. *Phytochemistry*, 62(3): 247-269.
- Von der Weid I, Artursson V, Seldin L, Jansson J. K. 2005. Antifungal and root surface colonization properties of GFP-tagged *Paenibacillusbrasilensis*. *World J Microbiol Biotechnol*, 21:1591–1597

- Waidyanatha, N., Yogorathnam and W. A. Ariyaratne. 1979. Effect of mycorrhizal infection on growth and uptake of phosphorus from two rock phosphate. *New Phytol.*, 82: 147-152.
- Wang S., W. Chang, W. Xiaojuan and J. Liang. 2008. Molecular Basics of Tripartite Symbiosis Formed by Rhizobia, Arbuscular Mycorrhizal (AM) Fungi and Legumes. *Chinese Journal of Applied & Environmental Biology*. 05-028.
- Wang, B. and Y. L. Qiu. 2006. "Phylogenetic distribution and evolution of mycorrhizas in land plants". *Mycorrhiza*. 16 (5): 299–363.
- Wang, N. and J. K. Daun. 2004. The chemical composition and nutritive value of canadian pulses. 19–29. *Canadian Grain Commission*. (CGC), Canada.
- Wang, N. D.W. Hatcher, R. Toews and E. J. Gawalko. 2009. Influence of cooking and dehulling on nutritional composition of several varieties of lentils (*Lens culinaris*). *LWT - Food Science and Technology*. 42 (4): 842-848.
- Wani, S. P. and Lee K. K. 2002. Population dynamics of nitrogen fixing bacteria associated with pearl millet (*P. americanum* L.). In biotechnology of nitrogen fixation in the tropics. University of Pertanian, Malaysia, 21-30.
- Whipps, J. M. 2004. Prospects and limitations for mycorrhizas in biocontrol of root pathogens. *Canadian Journal of Botany*, 82: 1198-1227.
- Xavier, L. and S. Boyetchko. 2002. Arbuscular mycorrhizal fungi as biostimulants and bioprotectants of crops. *Appl Mycol Biotechnol*, 2: 311–340.
- Xavier, L. J. C. and J. J. Germida. 2003. Selective interaction between arbuscular mycorrhizal fungi and *Rhizobium leguminosarum* bv. *viceae* enhance pea yield and nutrition. *Biol. Fertil. Soils*, 37: 262–267.
- Xiao, T., Yang, Q.S. Ran-W., X. GuoHua; S. Q. Rong. 2010. Effect of inoculation with arbuscular mycorrhizal fungus on nitrogen and phosphorus utilization in upland rice-mungbean intercropping system. *Agricultural-Sciences-in-China*. 9(4): 528-535.

- Xiurong, W. Qiang Pan, Fengxian Chen, Xiaolong Yan and Hong Liao. 2010. Effects of co-inoculation with arbuscular mycorrhizal fungi and rhizobia on soybean growth as related to root architecture and availability of N and P. *Mycorrhiza*, 1432-1890.
- Yadav, A. K., K. Varghese and T. Abraham. 2007. Response of biofertilizers, poultry manure and different levels of phosphorus on nodulation and yield of greengram (*Vigna radiata* L.) cv. K-851 *Agricultural-Science-Digest. Annals-of-Agricultural-Research*, 25(2): 320-326.
- Yadegari, M., H.A. Rahmani., G. Noormohammadi & A. Ayneband. 2008. Evaluation of Bean (*Phaseolus vulgaris*) Seeds Inoculation with *Rhizobiumphaseoli* and Plant Growth Promoting Rhizobacteria on Yield and Yield Components. *Pakistan Journal of Biological Sciences.*, 11: 1935-1939.
- Yano, K., A. Yamauchi and Y. Kono. 1996. Localized alteration in lateral root development in roots colonized by an arbuscular mycorrhizal fungus. *Mycorrhiza*, 6: 409–415.
- Zafar, M. Maqsood, M. Anser, M.R. Zahid Ali. 2003. Growth and yield of lentil as affected by phosphorus. *International Journal of Agriculture and Biology*. 5(1): 98-100.
- Zahran, H., H. 1999. *Rhizobium*–legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. *Microbiol Mol Biol R.*, 63: 968–989.
- Zaidi, A. and M. Saghir. Khan. 2006. Stimulatory effects of dual inoculation with phosphate solubilising microorganisms and arbuscular mycorrhizal fungus on chickpea. *Australian Journal of Experimental Agriculture* 47(8) 1016–1022.
- Zaidi, A., M. S. Khan and M. S. Aamil. 2003. Interactive effect of rhizotrophic microorganisms on yield and nutrient uptake of chickpea (*Cicerarietinum* L.). *European-Journal-of-Agronomy*, 19(1): 15-21.
- Zaidi, A., S. Khan and M. Aamil. 2004. Bioassociative effect of rhizospheric microorganisms on growth yield and nutrient uptake of greengram. *Journal of Plant Nutrition*, 27(4): 601-612.
- Zhao, D. and K. D. Hyde. 2001. Host specificity, host exclusivity, and host recurrence in saprobic fungi. *Mycol Res.*, 105:1449–1457.

Zhu, Y. G., F. A. Smith and S. E. Smith. 2003. Phosphorus efficiencies and responses of barley (*Hordeum vulgare* L) to arbuscular mycorrhizal fungi grown in highly calcareous soil. *Mycorrhiza*, 13(2): 93-100.