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Studies on pea (*Pisum sativum* L.) growth and productivity under agroforestry system: 1. Vegetative growth, chemical composition and nodulation status of pea under alley cropping system with two types of trees

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Abstract: Production of vegetables under agroforestry system says that it is a good alternative especially under limited resources. This study was undertaken to find out the possibility of growing pea with highly adaptable two tree species; the Egyptian river hemp (*Sesbania sesban*) and white lead tree (*Leucaena leucocephala*) under two levels of nitrogen fertilizer. The results indicated that plant fresh and dry weights of pea were significantly affected with alley cropping treatments. Moreover, pea allied with *Sesbania*+1/2 recommended dose (RD) of N produced the heaviest plant fresh and dry weight. While, sole pea plants inoculated with *Rhizobium* treatment followed by pea allied with *Sesbania*+1/2 RD gave the highest number of main branches. Alley cropping system with *Sesbania* or *Leucaena*+1/2RD showed the best result for the total nitrogen %. Treatment with *Rhizobium* followed by growing with *Sesbania*+1/2 RD produced the highest N uptake values. On the other hand, pea with *Sesbania*+1/2 RD gave the highest % of K uptake. For nodulation status, alley cropping system of pea with *Sesbania* and *Leucaena* plus half of nitrogen RD significantly increased the pea fresh and dry nodules weight as well as the number of nodules compared to the other treatments. Thus, it appears that alley cropping system has great benefits on peas but still moderate N fertilization is the key factor in defining the productivity and sustainability of the production in Aswan, Egypt.

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INTRODUCTION

Pea (*Pisum sativum* L.) is one of the most important leguminous vegetable crops grown during winter season for local consumption and exportation in Egypt. The pods of pea contain a great amount of protein and carbohydrates. So that, pea is considered as one of the most important sources in human nutrition not only in Egypt but worldwide (Zaghloul *et al*., 2015). Pea high seed yield and its components required high soil fertility (Elkhatib *et al*., 2007).

Low soil fertility is widely known as a main cause contributing to low plant productivity (Sanchez, 2002; Vanlauwe and Giller, 2006). The amount of resources and the multiplicity of programs devoted to soil improvement technologies attest to the enormity of the problem in Africa (Haggblade *et al*., 2004). The degradation of soil fertility in many countries of Africa is caused by two major factors. The first factor is the increasing in human population that has led to a reduction in per-capita land availability. The second reason is none or suboptimal use of inorganic fertilizers due to high cost of the input (Scoones and Toulmin, 1999; Ajayi *et al*., 2003).

Agroforestry practices using legume species such as *Leucaena leucocephala, Sesbania sesban, Gliricidia sepium* and *Tephrosia vogelli* replenish soil fertility through biological fixation of atmospheric nitrogen and recycling of nutrients, thus contributing to conservation of natural resources. In addition to supplying nitrogen and improving crop yield, the plant species also increase soil organic matter and improve soil chemical, physical and biological conditions (Kwesiga *et al.*, 2003; Phiri *et al.*, 2003; Akinnifesi *et al*., 2006; Mafongoya *et al.*, 2006; Sileshi *et al.*, 2007; Akinnifesi *et al.*, 2008), act as carbon sink to mitigate climate change (Makumba *et al.*, 2007; Kaonga and Bayliss-Smith, 2009), generate multiple ecosystems services (Sileshi *et al.*, 2007) and provide fuel-wood for household energy (Kwesiga and Coe, 1994).

Among the agroforestry-based practices, alley cropping system that is based on the use of legumes has received significant attention. "Improved tree fallows" involve the deliberate planting of fast growing nitrogen-fixing trees or woody shrub species for one to two years, followed by one or two years of cropping (Sanchez, 1999), and may go through several fallow-cropping-fallow rotational cycles. The underlining science of the practice builds on the knowledge that nitrogen is the most limiting macro nutrient in the soil, but it is highly abundant in the atmosphere.

In this respect, alley cropping with crops grown between hedgerows and tree prunings used as mulch or green manure can also provide significant N to the interspersed crop. Beans (*Phaseolus spp*.) grown between *Erythrina poeppigiana* rows and supplied prunings from these trees yielded 15% to 50% more than beans grown in monoculture (Henriksen *et al*., 2002). *Sesbania sp*. has been used similarly for alley cropping in different crops. Nevertheless, Giller (2001) pointed to problems with this system, including competition for moisture between trees and crop plants, and declining yield benefits over time on infertile or acid soils. Keeping in view the chemical and biofertilizers are important and critical factors affecting production. Meanwhile, the main objective of the current study is to find out the advantages of alley cropping system of pea (*Pisum sativum*) with two different tree species; the Egyptian river hemp (*Sesbania sesban*) and white lead tree (*Leucaena leucocephala*) in addition to, different levels of N fertilization and biofertilizers. The effect of alley cropping was studied on pea vegetative growth, nodulation status as well as chemical compositions.

MATERIALS AND METHODS

Experimental site

An alley cropping system of pea and two different tree species was established during 2012/2013 and 2013/2014 seasons at Kom-Ombo Tropical Farm, Aswan Botanical Garden, Hort. Res. Inst., Agric. Res. Center, Egypt (N 24°05' E 32°53') on a loamy sandy soil.

Soil analysis

Soil samples from 0-15 cm depth was taken from each plot before planting the two tree species in 2010 and after the two cropping seasons of pea plants. These samples were bulked, subsampled and the analysis was carried out according to Carter and Gregorich (2008). Chemical and physical properties of experimental soil before and after alley cropping are presented in Table 1.

Procedure

A field experiment was adopted to study the effect of growing pea with two species of legume trees with or without 1/2 recommended N dose (RD) or 1/4 N (RD) and sole plants inoculated with *Rhizobium* on vegetative growth, chemical constituents and nodulation status of pea plant cv. Master-B. The sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended dose (RD) were considered as control treatment.

The seeds of the used legume trees; *Leucaena leucocephala* and *Sesbania sesban* were soaked in boiled water 95°C till room temperature extended to 24 hours then were sown in rows at 2.1m apart in June 2012 by using 5g seed/m and allowed to grow without cutting for 4 months and when the first season of pea crop came *leucaena* or *sesbania* trees were about 1m in height.

Pea, Master-B cv. seeds were obtained from the Agronomy Res. Inst. ARC, Giza, Egypt. Seeds were sown in hills 15cm apart in rows spaced 70cm in between *leucaena* or *sesbania* trees. Two seeds were planted per hill and thinned to one plant 15 day after germination. Pea seeds were sown on October 16, 2012 and 2013. The field was immediately irrigated after planting and all other agronomical practices except those under investigation were kept normal. The experimental area was applied with $15m^3$/fed of well decomposed farmyard manure as well as 300 kg/fed of calcium superphosphate (15.5% P_2O_5) and mixed with the soil during bed shaping, while 50 kg/fed potassium sulphate (48% K_2O) was added in three equal portions i.e. after germination, at anthesis and at pod formation stage. The plot area was $21m^2$ (4.2 x 5m), which consisted of 7 ridges (every plot contained three rows of trees and 4 rows of pea plants according to the treatment), 5.00 m length and 0.70 m width. There was a 1.5m border area between plots and there were three replications.

Preparation of Rhizobium Inocula

The biofertilizer inocula for sole pea plants were prepared in specific broth media. *Rhizobium leguminosarum* bv. *Viciae* was grown in yeast extract mannitol (YEM) broth (Somasegaran and Hoben, 1985) for seven days. Before sowing, pea seeds were surface sterilized with acidified 0.01% $HgCl_2$ for 5 minutes and after serial washings with sterilized water, they were inoculated by soaking for one hour in the prepared inocula (1ml contains about 109 cfu). An amount of Arabic Gum (20%) was added as adhering agent then, spread in plates and allowed to air drying before sowing.

Treatments and experimental design

The following treatments for plots containing sole pea or pea allied with *leucaena* or *sesbania* trees were as follow:

(1) Sole pea plants that fertilized by 50 kg N/fed ammonium sulfate (added after two weeks from planting)+100 kg N ammonium nitrate as a recommended N dose “RD” (applied in two equal doses at anthesis and pod formation stage) were considered control plants.

Table (1): Physical and chemical properties of the soil before and after alley cropping of pea plants with the Egyptian river hemp (*Sesbania sesban*) and white lead tree (*Leucaena leucocephala*) trees during the two studied seasons of 2011/2012 and 2012/2013.

Soil properties	Before alley cropping, 2010	After alley cropping	
		2011/2012	2012/2013
Particle size distribution %			
Coarse sand	29.80	29.80	29.80
Fine sand	47.55	47.55	47.55
Slit	7.95	7.95	7.95
Clay	14.70	14.70	14.70
Texture-class	Loamy sand	Loamy sand	Loamy sand
Chemical analysis %			
E.C. ds/m	0.23	0.27	0.30
pH	8.60	8.3	8.2
O.M. %	0.33	0.49	0.53
Soluble anions (meq/L)			
HCO_3^-	1.79	1.70	1.25
Cl^-	0.37	0.37	0.31
SO_4^-	0.53	0.53	0.42
Soluble cations (meq/L)			
Ca^{++}	1.56	1.56	1.75
Mg^{++}	0.49	0.49	0.52
Na^+	0.49	0.49	0.44
K^+	0.22	0.16	0.27
N%	0.21	0.23	0.31

(2) Sole pea plants but seeds were inoculated at sowing time with nitrogen fixing bacteria of *R. leguminosarum* as described before.
(3) Alley cropping of *leucaena* with pea plants without N fertilization.
(4) Alley cropping of *leucaena* with pea plants received 1/2 N (RD).
(5) Alley cropping of *leucaena* with pea plants received 1/4 N (RD).
(6) Alley cropping of *sesbania* with pea plants without N fertilization.
(7) Alley cropping of *sesbania* with pea plants received1/2 N (RD).
(8) Alley cropping of *sesbania* with pea plants received1/4 N (RD).
Therefore, a Randomized Complete Blocks Design (RCBD) was used in the present experiment. Plots were arranged into the field and distributed into three replicates; each contains three plots.

Date recorded

Growth characteristics

Ten to five plants were randomly sampled from each plot near maturity to determine plant height (cm), number of branches/plant and plant fresh and dry weight (g).

Chemical constituents

For chemical analysis, a random sample of each treatment was taken to determine NPK contents of the vegetative parts as follows: N by Kjeldahl method (Chapman and Pratt, 1961), P by spectrophotomic according to the procedure of John (1970) and K by flame photometer as described by Jackson (1973).

Nodulation status

Five plants from each plot were randomly taken after 50 days from sowing to investigate the number of nodules/plant, fresh and dry weight of nodules (g).

Statistical analysis

The analysis was carried out according to Snedecor and Cochran (1989). The differences between the mean values of various treatments were compared by least significant differences (L.S.D. at 5%).

RESULTS

Vegetative growth of pea plants

Plant fresh and dry weight

Results of plant fresh and dry weights shown in Figure (1) indicated that plant fresh weight was significantly affected by alley cropping treatments under the current study in both seasons. Growing pea with *Sesbania*+1/2 RD of N followed by sole plants inoculated with *Rhizobium* produced the heaviest fresh weight in the mean of seasons (431.1g and 426.2.6g in the 1st season and 435.6g and 437.9g in the 2nd season, respectively) compared to the sole plants received full RD of N (control) and other treatments (Fig.1 A and B). On the other hand, plant dry weight was significantly affected under alley system in both seasons (Fig.1 C and D). While, there were no significantly differences between *Rhizobium* and recommended N fertilization treatments. The highest value (42.6g) in both seasons was noticed in plant dry weight as a result of *Rhizobium* treatment compared to other treatments. Moreover, alley cropping with *Sesbania*+1/2 RD of N resulted in the highest values of plant dry weight in both seasons compared to the other allay cropping treatments.

Plant height and number of main branches

The effect of alley cropping system with *Sesbania* or *Leucaena*, inoculation with *Rhizobium*, 1/2 N (RD) or 1/4 N (RD) on plant height (cm) and number of main branches of pea plants, Master-B cv. during two successive seasons; 2012/2013 and 2013/2014 are shown in (Fig. 2). It could be concluded that sole plants which inoculated with *Rhizobium* significantly decreased the plant height in the first season, in comparison with the control treatment. Whereas, the highest values of the trait were resulted from planting pea with *Sesbania*+1/2 recommended N fertilization compared to other treatments as shown in Figure (2 A and B).

The number of main branches was significantly increased by using inoculated plants, in comparison with that of the control. Moreover, the differences among alley treatments were significant for the number of main branches in both seasons. *Sesbania*+1/2 recommended N dose treatment resulted in the highest values for the trait, while pea planted with *Leucaena* trees only gave the lowest no. of main plant branches in both seasons (Fig. 2 C and D).

Chemical composition of pea plants

Total nitrogen

Data in Figure (3) represented the effect of alley cropping system on the total nitrogen which measured before flowering in the aerial parts of pea plants. Treating pea seeds with *Rhizobium* not significantly increased the total nitrogen compared to the control. Moreover, pea plants with *Sesbania*+1/2 RD of N followed by *Leucaena*+1/2 RD of N treatments had the best result of the total nitrogen in both seasons (Fig. 3 A and B). However, the lowest values of the total nitrogen were recorded with pea plants that planted under alley cropping with *Leucaena* only.

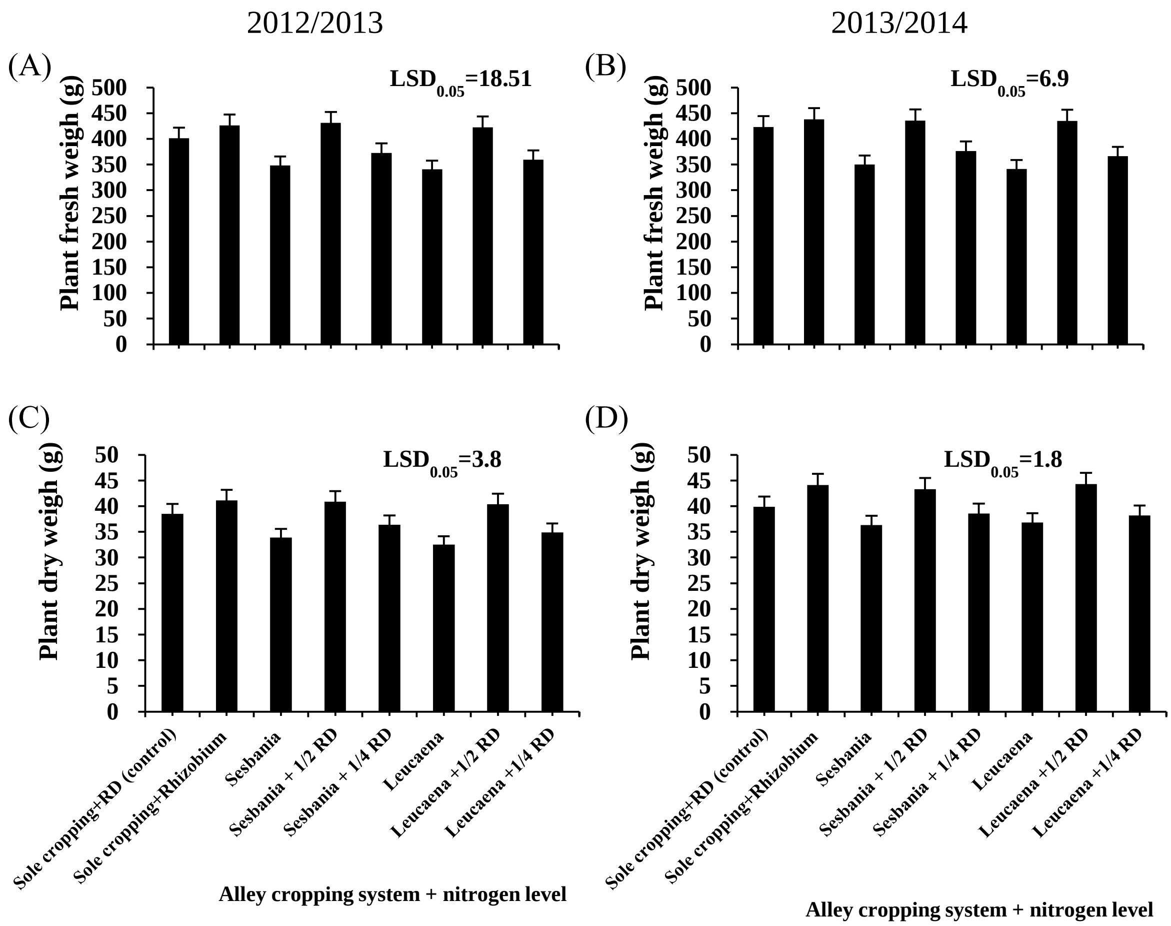

Fig. 1 Effect of alley cropping system with *S. sesban* or *L. leucocephala* with or without 1/2 N (RD) or 1/4 N (RD) and sole plants inoculated with *Rhizobium* on plant fresh weight (g) and plant dry weight (g) of pea plants; Master-B cv. during two successive seasons; 2012/2013 (A and B) and 2013/2014 (C and D), respectively. Control sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended N dose (RD).

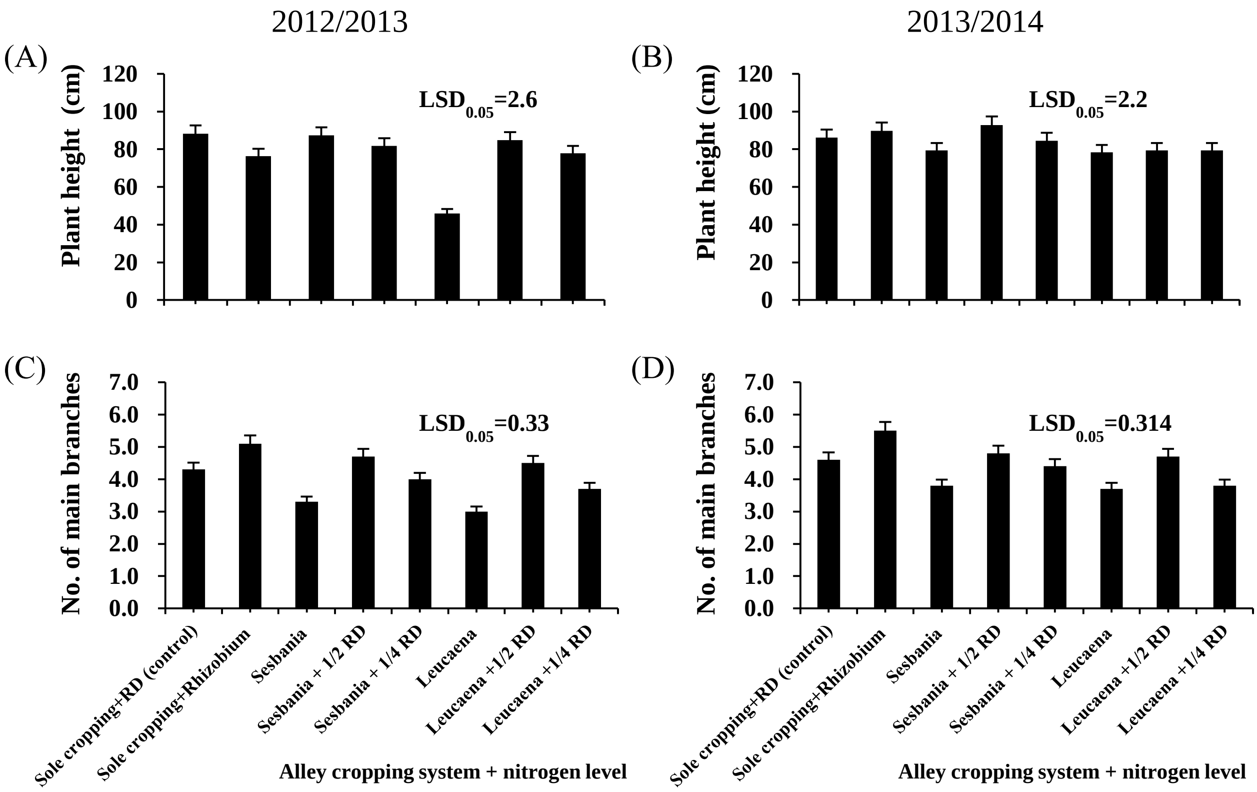

Fig. 2 Effect of alley cropping system with *S. sesban* or *L. leucocephala* with or without 1/2 N (RD) or 1/4 N (RD) and sole plants inoculated with *Rhizobium* on plant height (cm) and number of main branches of pea plants; Master-B cv. during two successive seasons; 2012/2013 (A and B) and 2013/2014 (C and D), respectively. Control sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended N dose (RD).

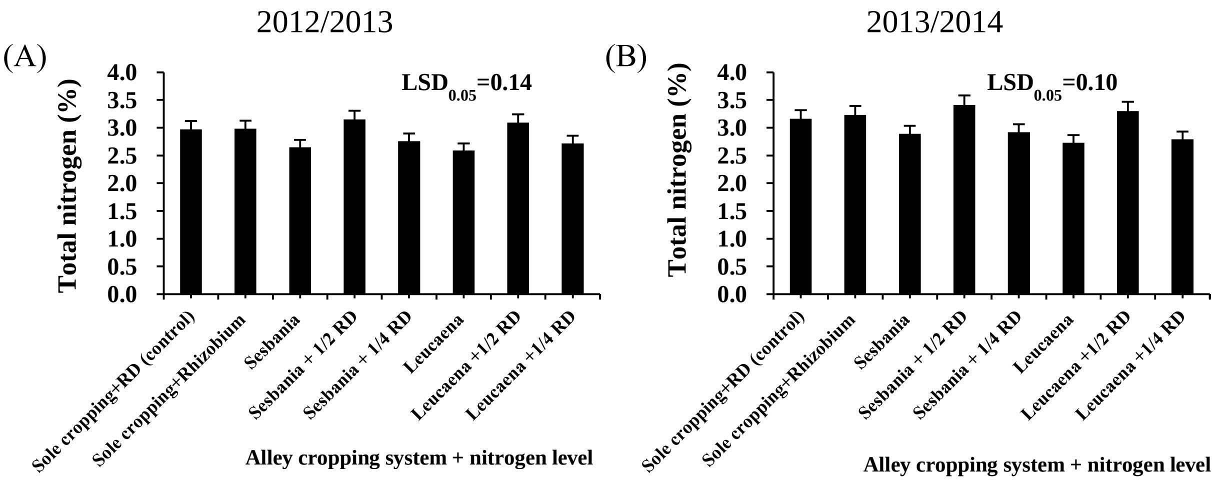

Fig. 3 Effect of alley cropping system with *S. sesban* or *L. leucocephala* with or without 1/2 N (RD) or 1/4 N (RD) and sole plants inoculated with *Rhizobium* on total nitrogen % of pea plants Master-B cv. during two successive seasons; 2012/2013 (A) and 2013/2014 (B), respectively. Control sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended N dose (RD).

NPK uptake (%)

Results shown in Figure (4) indicated that N uptake (%) for pea plant was significantly affected by alley cropping treatments under the present study in both seasons. The N uptake of pea plant was increased as a result of inoculation with *Rhizobium* compared to the control. Also, *Rhizobium* followed by *Sesbania*+1/2 recommended N dose treatments produced the highest values of this character in the mean of seasons compared to the other treatments while, pea plants with *Leucaena* only produced the lowest one (Fig. 4 A and B).

There were not significant differences between *Rhizobium* and full recommended N fertilization (control) on P uptake except for the second season. Also, data in (Fig. 4 C and D) illustrated that alley cropping system with *Sesbania* or *Leucaena* trees had statistical significant effect on the P uptake percentage for pea plants. *Leucaena*+1/4 recommended N fertilization increased P uptake. Generally, it was noticed that there was an increase in this trait in the two studied seasons by applying alley cropping treatments compared to the control.

Results in (Fig. 4 E and F) showed that K uptake (%) was significantly affected by alley cropping or *Rhizobium* treatments under the present study in both seasons. The K uptake of pea plant was decreased in the two seasons as a result of inoculation with *Rhizobium* (159.07% and 174.7%) compared to the control. While, pea with *Sesbania* +1/2 RD of N treatment produced the highest percentage of K uptake in the mean of seasons compared to the other treatments (225.06% and 222.31%, respectively). On contrary, pea which planted with *Leucaena* only had the lowest K uptake percentage in both season (149.85% and 167.24%, respectively).

Nodulation status

The effect of alley cropping with *Sesbania* or *Leucaena* trees, inoculation with *Rhizobium* and/or 1/2 N (RD) or 1/4 N (RD) on fresh weight of nodules, dry weight of nodules and number of nodules/plant is shown in Figure (5). In general, the differences among treatments were highly significant. The fresh weight of nodules (Fig. 5 A and B), dry weight of nodules (Fig. 5 C and D) and number of nodules (Fig. 5 E and F) for pea plants were significantly increased as a result of *Rhizobium* treatment in comparison with that of recommended fertilization treatment (control). Regarding the influence of alley cropping treatments on the fresh weight of nodules/plant, it was shown that plants allied with *Sesbania* or *Leucaena*+1/2 RD of N fertilization had the highest values compared to the control and the other treatments in the two seasons of the experiment.

DISCUSSION

Alley cropping system offered production of various vegetables under different shade conditions by maximum utilization of natural resources (Sanchez, 1999; Olasantan, 2000; Taleb, 2003; Sileshi *et al.*, 2007). This system had wider implications and potentials with different crops such as; carrot, chilli, brinjal, onion, garlic and turnip which allied with some fruit tree such as guava, lemon, papaya, banana etc. to give high yield (Mustafa, 1997; Phiri *et al.*, 2003).

The growth of pea was differed under different allay cropping treatments. The highest values of the growth parameters were noticed with *Sesbania* or *Leucaena*+1/2 RD of N. For the nodule parameters, the alley treatments significantly gave more nodule parameters over that of the sole plants inoculated with *Rhizobium* or fertilized with RD of N. The influence of alley cropping treatments was also clear on NPK uptake % and total N %. Pea plants allied with *Sesbania* and *Leucaena*+1/2 RD of N had the highest values compared to the other treatments in the two seasons of the experiment. *Sesbania* and *Leucaena* trees readily, like most other members of the family leguminosae, they form symbiotic relationship with the nitrogen fixing bacteria (Halliday and Somasegaran, 1983; Okogun *et al*., 2000). The bacteria penetrate young rootlets and multiply to form nodules. They absorb atmospheric nitrogen and transform it to ammonia which in turn is converted to other nitrogen containing organic and inorganic compounds. Onim *et al.* (1987) speculated that the perennial *Sesbania* species could fix up to 600 kg N/ha/year.

The sole pea plants inoculated with *Rhizobium* gave significantly higher nodule weight and number over that of the sole plants fertilized with full RD of N (control). This indicated that indigenous bacteria were less effective than the inoculated one. The response to inoculation and the competitive success of inoculant rhizobia were inversely related to number of indigenous rhizobia (Somasegaran and Hoben, 1985; Janice *et al*, 1991). Generally nitrogen fixation activity was reduced by high nitrogen application in crop rotation (Takuji, 2013). According to Gulden and Vessey (1997) low levels of NH_4^+ in nutrient solution can stimulate nodulation in pea. The obtained results pointed out that growing of pea plants between legume trees without N fertilization treatments resulted in low values for the growth parameters of pea. These results were in accordance with that of many researchers (Olasantan, 2000; Ebeid *et al.,* 2015; Kang and Mulongoy, 1992; Okogun *et al.,* 2000).

Therefore, it might be practical to apply some N-fertilizer to the allied crop in the agroforestry system. Moreover, our results confirmed that *Leucaena* or *Sesbania* rooting patterns are different from those of pea plant. Therefore, the two tree species has low capacity to compete with crops, and are capable of retrieving nutrients and water from sub-soil beyond the rooting depth of annual crops as also stated with Isaac *et al.* (2003).

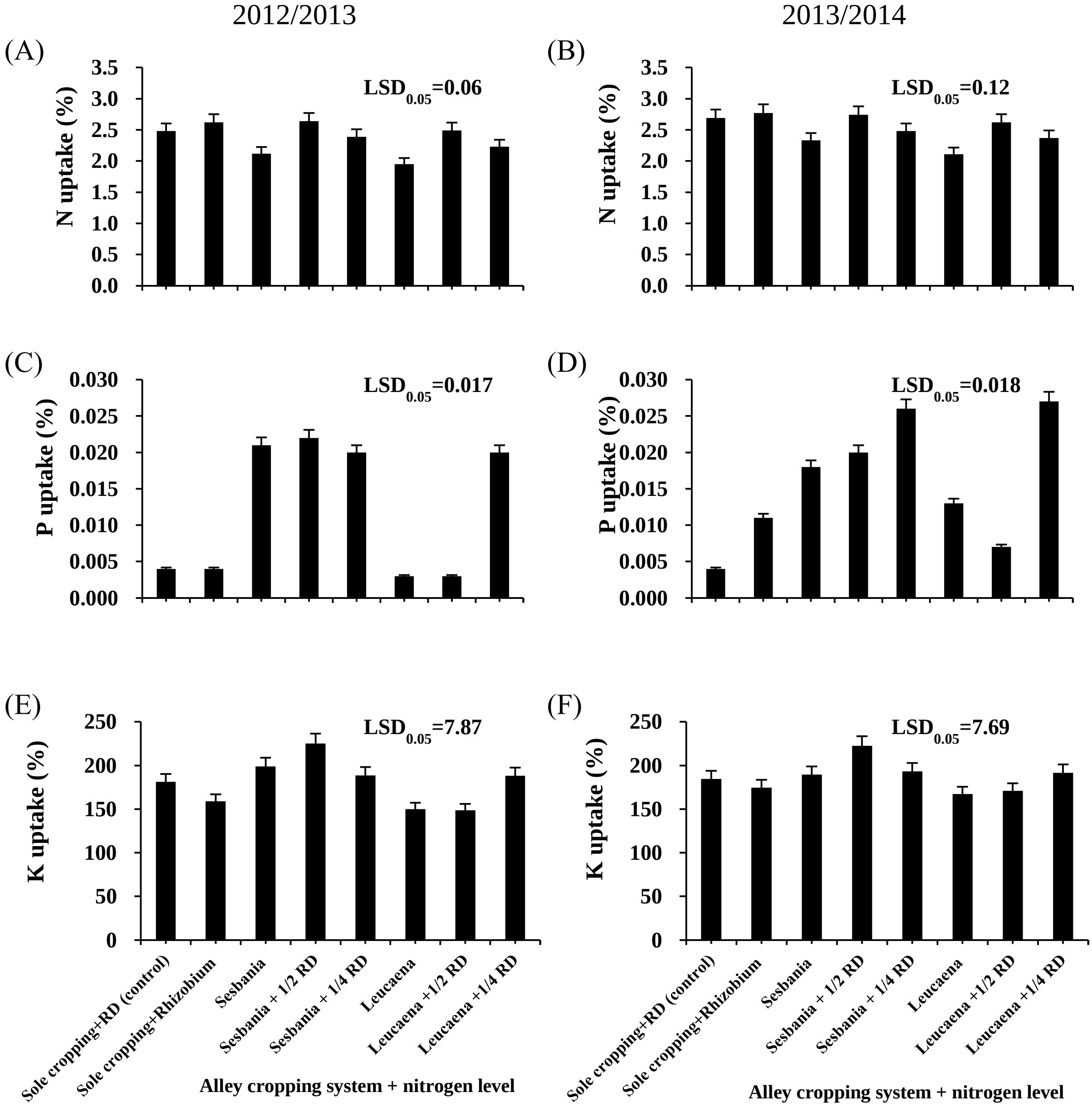

Fig. 4 Effect of alley cropping system with *S. sesban* or *L. leucocephala* with or without 1/2 N (RD) or 1/4 N (RD) and sole plants inoculated with *Rhizobium* on N (A and B), P (C and D) and K (E and F) uptake % of pea plants; Master-B cv. during two successive seasons; 2012/2013 and 2013/2014, respectively. Control sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended N dose (RD).

CONCLUSION

Integrating *Sesbania* or *Leucaena* with pea and moderate nitrogen fertilization produced higher total growth parameters of pea. Alley cropping with *Sesbania* can be used as an alternative tree legume instead of *Leucaena*. Growing of the legume crops as pea in an alley cropping system appears to be viable agroforestry practices. From the results on effectiveness of the alley system, it could be concluded that growing pea with half of the recommended N dose in 4.2m wide alleys of *Sesbania or Leucaena* had great possibilities to improve pea vegetative growth, nodulation status and chemical composition.

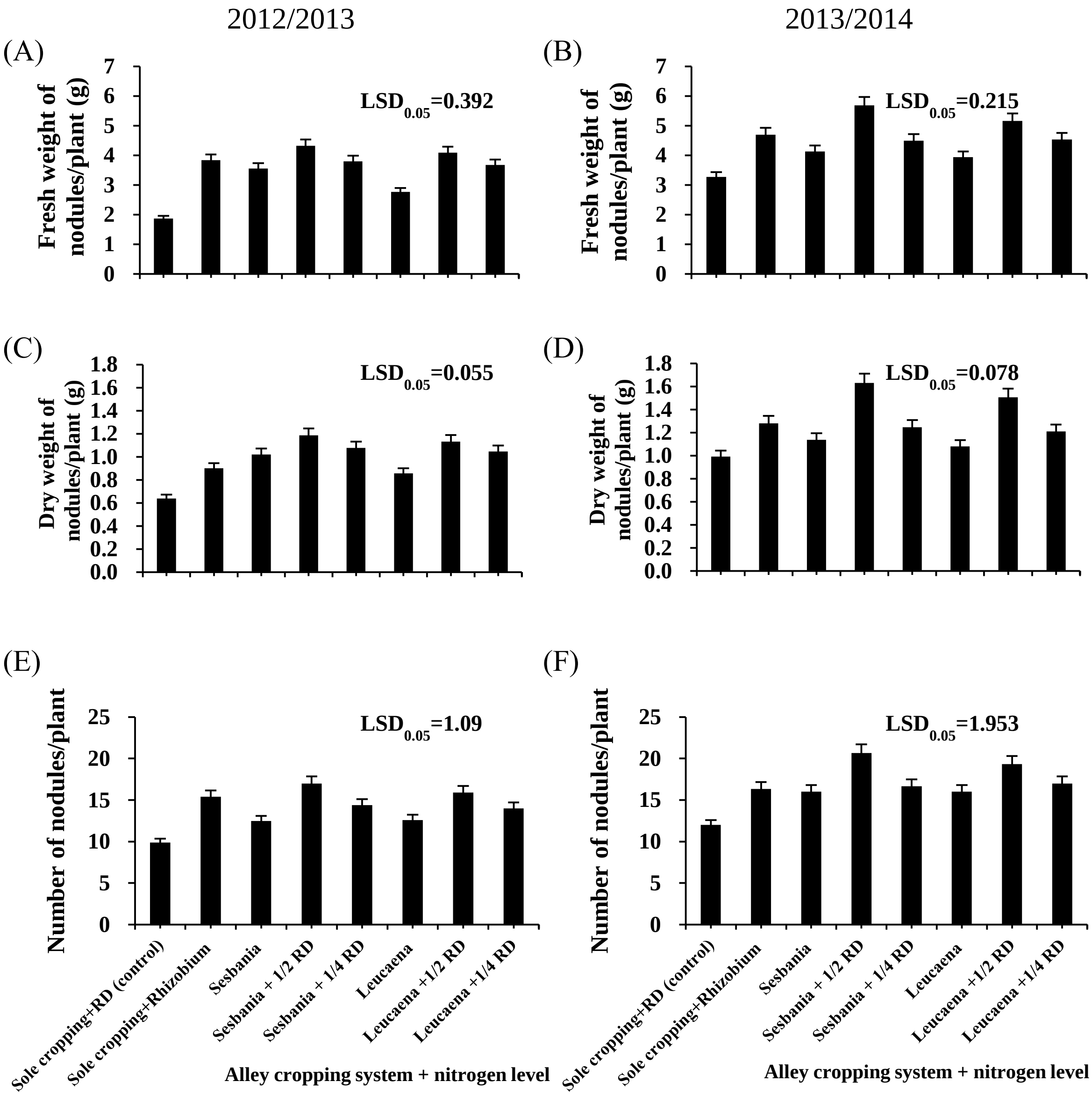

Fig. 5 Effect of alley cropping system with *S. sesban* or *L. leucocephala* with or without 1/2 N (RD) or 1/4 N (RD) and sole plants inoculated with *Rhizobium* on fresh weight of nodules/plant (g) (A and B), dry weight of nodules/plant (g) (C and D) and No. of nodules/plant (E and F) of pea plants Master-B cv. during two successive seasons; 2012/2013 and 2013/2014, respectively. Control sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended N dose (RD).

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