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Studies on pea (*Pisum sativum* L.) growth and productivity under agroforestry system: 2. Yield and seed quality of pea under alley cropping system with two types of trees

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Abstract: Alley cropping system can play a significant contribution of the multiple components of yield especially in hot regions. This study was carried out at the Tropical Farm of Kom-Ombo, Aswan, Egypt during 2012/2013 and 2013/2014 seasons to investigate the value of growing pea plants under alley cropping with two tree species; the Egyptian river hemp (*Sesbania sesban*) and white lead tree (*Leucaena leucocephala*) and three levels of nitrogen fertilization. Sole pea plants which received the recommended N dose (RD) were considered as control. The results indicated that yield and yield components of pea plants were significantly affected with alley cropping. Moreover, the highest values of seed fresh weight were noticed in pea plants allied with *Leucaena*+1/2 RD. On the other hand, pea allied with *Sesbania*+1/2 RD of N gave the best results for seeds dry yield, number of seeds/pod, seeds weight/pod, weight of 100 seeds, fresh weight of pod and pod length and diameter. For seed chemical compositions and quality, it was noticed that the lowest NO_3 and NO_2 contents were due to growing pea plants with *Leucaena* or *Sesbania* trees without any N fertilization. The highest seeds total carbohydrate % was for plants allied with *Sesbania*. However, pea plants allied with *Sesbania*+1/2 RD gave the highest seeds protein %. The land equivalent ratio of pea with *Sesbania* or *Leucaena* showed that this system had better seed yield performance when compared to sole cropping. Therefore, alley cropping with legume trees can reduce fertilizer requirement for vegetable production. Pea, a cool season crop, can be grown under the hedgerow of trees in hot region like Aswan, Egypt and give more production than sole system.

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INTRODUCTION

Pea (*Pisum sativum* L.) is a leguminous, annual herbaceous plant with a one-year life cycle. Pea is considered a cool season crop with planting taking place from winter to early summer depending on the location. Seeds may be planted when the soil temperature reaches 10ºC, with plants ideally growing at temperatures of 13-18ºC. Peas do not thrive in summer heat or lowland tropical climates, but they do grow well in cooler high altitude tropical areas (Oelke *et al.*, 1991). Multi-storied agroforestry system offers production of various vegetables under different shade conditions by maximum utilization of natural resources (Taleb, 2003). The average pea yield in agroforestry systems was 30 to 50% higher, especially in hot climate region. Hedgerows of *Leucaena* and *Gliricidia* acted as windbreaks. Consequently, soil moisture content in the top 0-5cm layer in agroforestry systems was generally higher than that in the control during both wet and dry seasons (Lal, 1989).

Nitrogen fixing legumes have great potential for inclusion in African farming systems, whether for grain or fodder, or in fallow periods either as a green manure or a tree fallow. Trees will rarely be worth including simply for their effect on soil fertility, but this may be an important additional benefit where trees are used for other or multiple functions, such as fruit, fuelwood, timber or stakes. Large amounts of nitrogen can potentially be introduced into the system through fixation by legumes (Kwesiga and Coe, 1994; Sileshi *et al.,* 2007). However, the use of different food, herbaceous (green-manure) and forage legumes in cropping systems, either as intercrops or in rotations with other crops, for improving soil fertility is a well-known practice in the tropics.

Perennial tree legumes may have greater scope to replenish soil fertility than annual grain legumes by their ability to exploit the residual water and subsoil nutrients that crops cannot utilize, withstand drought, and hence produce higher biomass. Their year-round growth may lead to higher biological N fixation (Giller *et al.*, 1997; Giller, 2001). Other advantages of perennial legumes include an absence of recurring establishment costs, opportunity to grow crops simultaneously without sacrificing land (Kang *et al.*, 1990) and improved soil physical conditions and higher water infiltration because of their root activity (Sanchez, 2002).

Leucaena leucocephala (L.) and *Sesbania sesban* (L.) are important agroforestry species. The two species are within the family of Leguminosae and therefore, they have the ability to improve soil through the fixation of atmospheric nitrogen. The original home of these species is open to conjecture but *S. seban* is thought to be native to Egypt. However, in alley cropping system, food or fodder crops are grown between hedgerows of shrubs and trees, preferably leguminous species. A wide range of hedgerow species has been tested in various trials in different climates and soils. Much work has been carried out on species such as *Leucaena* and *Sesbania* (Duguma *et al.*, 1988; Kwesiga and Coe, 1994; Krishna and Allolli, 2005; Lawson and Kang, 1990). However, tree legume fallows of one to 3 year durations have shown to increase N availability to subsequent crops on N deficient soils. Barrios *et al.* (1997) reported increases in soil inorganic N, and N mineralization in *S. sesban* (L.) Merr fallows in Eastern Zambia. Keeping in view the chemical and biofertilizers as important and critical factors affecting productivity of pea, the present study was undertaken to find out the possibility of growing pea, this an important crop with two tree species; the Egyptian river hemp (*S. sesban*) and white lead tree (*L .leucocephala*). The response of yield and its components of pea plants grown under alley cropping system were studied.

MATERIALS AND METHODS

Alley cropping system

An alley cropping system of pea and two tree species was established during two successive seasons of 2012/2013 and 2013/2014 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.

A field experiment was adopted to study the effect of allied system with two species of legume trees under different level of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose "RD") on yield and its components of pea plant cv. Master-B. Sole pea plants inoculated with *Rhizobium* were also evaluated. 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; white lead tree (*Leucaena leucocephala*) and the Egyptian river hemp (*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 planting and agricultural practices

Master-B cv. seeds were obtained from the Agronomy Res. Inst. ARC, Giza, Egypt. Seeds were sown in hills 15cm apart in rows spaced 70 cm 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), 5.00m length and 0.70m 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.
(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 (pea+alley, pea+alley+1/4 RD and pea+alley+1/2 RD).

Date recorded

Yield and its components

The green pods of three ridges of each plot were harvested three times and the dry pods of the other three ridges were harvested at the end of experiment, threshed and the following traits were calculated:
-Average seed fresh weight (ton/fed.).
-Average seed dry weight (ton/fed.).
-Average number of seeds/pod.
-Average seeds weight/pod (g).
-Average weight of 100 seeds (g).
-Average weight of fresh pod (g).
-Average pod length (cm).
-Average pod diameter (cm).

Chemical constituents

For chemical analysis, representative samples of 100 g. of green seeds from each experimental plot were taken randomly to determine nitrite (NO_2) and nitrates (NO_3). Total carbohydrate % was determined by microkjeldhl method and protein % content as described by A.O.A.C. (1985).

Land equivalent ratio (LER)

In this experiment, a program of alley cropping system of pea with two different trees was developed and a series of parameters were measured, such as: agronomical parameters (yield components and seed yield), chemical contents (NO_2, NO_3, protein% and total carbohydrates % of the seeds) to compare land equivalent ratio (LER) as competition parameters. The (LER) was calculated using the following formula:
LER = Yi.c.1/Ys.c.2
Where:
Yi.c.1 - yield in intercropping.
Ys.c.2 - yield in sole crop.
When LER values are higher than 1, it means that there is an advantage of alley cropping system in terms of the use of resources for the plant growth compared to sole cropping. When LER values are lower than 1, it means that sole cropping use the resources more efficiently in comparison with intercropping (Sullivan, 1998).

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. 5%).

RESULTS

Average fresh and dry seed yield

Data shown in Figure (1) represented the effect of alley cropping system with *Sesbania* or *Leucaena* and sole plants which inoculated with *Rhizobium* on the fresh and dry yield of seeds (ton/fed) of pea plants during 2012 and 2013 seasons, respectively. Figure (1A and B) showed that seed fresh weight was significantly affected with alley cropping treatments. Moreover, the highest values were noticed in pea growing with *Leucaena*+1/2 RD of N (4.56 and 4.59 ton/fed.) and *Sesbania*+1/2 RD of N (4.36 and 4.65 ton/fed.) in both seasons. Concerning the effect of *Rhizobium* treatment, seed fresh yield was significantly increased (3.66 and 4.05 ton/fed.) compared to the control treatment (3.31 and 3.89 ton/fed) during the two studied seasons as indicated in Figure (1A and B, respectively). It was obvious that the increment in seed fresh yield was noticed in the second season in comparison with that in the first season.
Pea plant which allied with *Sesbania*+1/2 RD of N followed by *Leucaena*+1/2 RD of N resulted in the best value of seeds dry yield in both seasons compared to the control and these treatments were not significantly different from sole plants which treated with *Rhizobium.* However, the lowest values of dry yield were recorded with pea that planted under *Leucaena* without any nitrogen fertilization (Fig. 1 C and D).

Average No. of seeds and seeds weight/pod

Number of seeds/pod of pea plants was significantly affected by *Rhizobium* inoculation treatment since it was increased, especially in the second season, compared to the control (full RD of N) as clear from Figure (2 A and B). On the other hand, seeds number was increased as a result of planting pea with *Sesbania*+1/2 RD of N and *Leucaena*+1/2 RD of N, respectively in comparison with that of the other alley treatments. However, differences between alley treatments were significance in the two studied seasons.

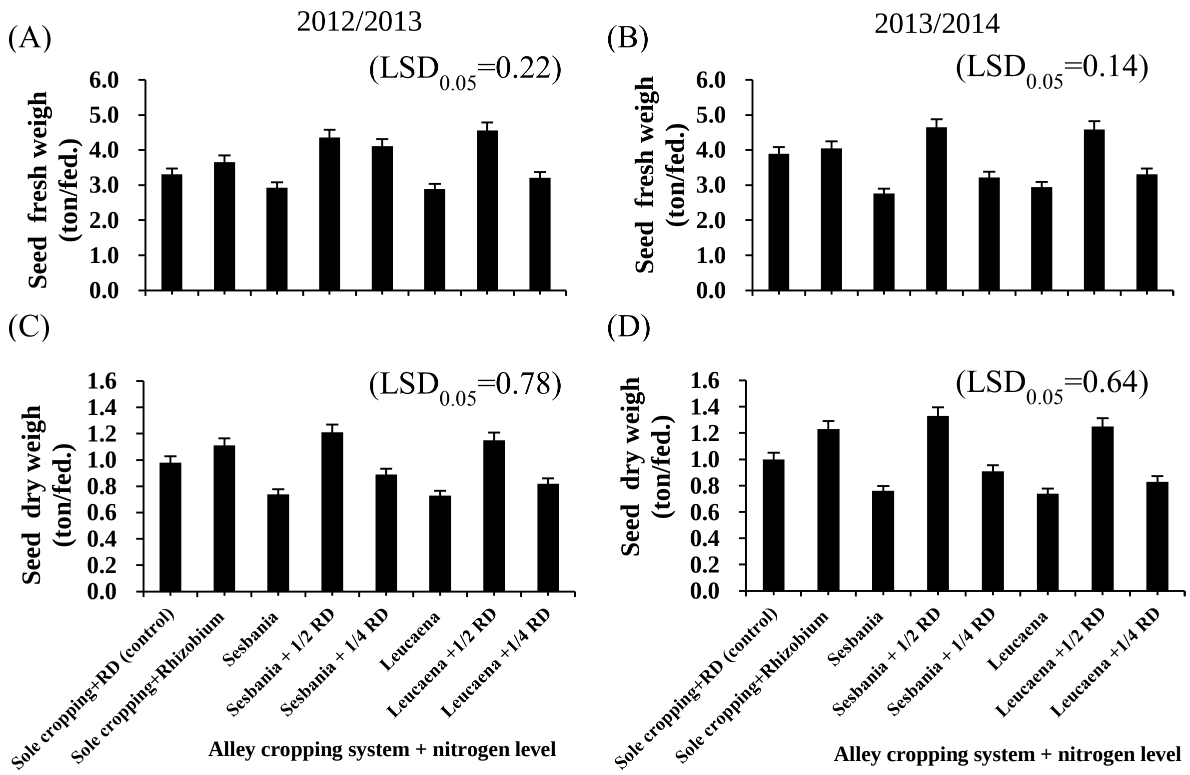

Fig. 1 Effect of alley cropping system with *S. sesban* or *L. leucocephala* under different levels of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose "RD") and sole plants inoculated with *Rhizobium* on seed fresh weight (ton/fed.) and seed dry weight (ton/fed.) of pea plants; 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).

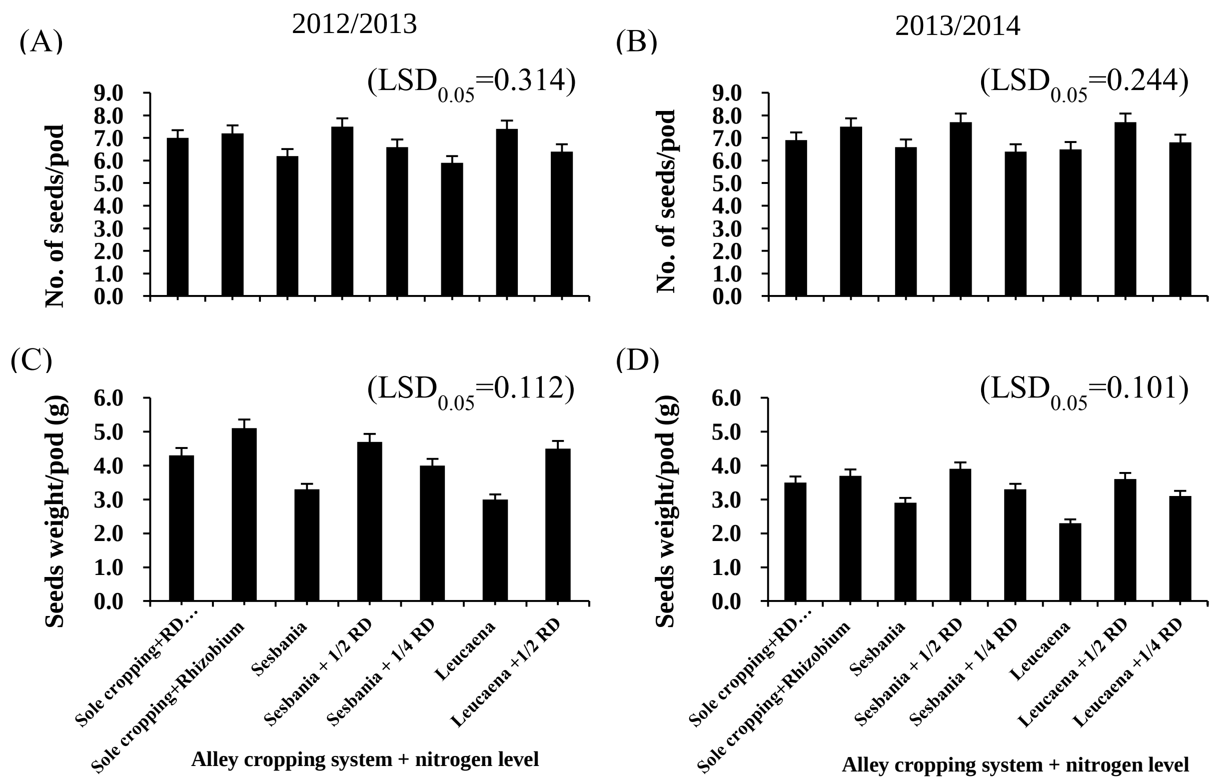

Fig. 2 Effect of alley cropping system with *S. sesban* or *L. leucocephala* under different levels of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose "RD") and sole plants inoculated with *Rhizobium* on number of seeds/pod and seed weight/pod (g) of pea plants; Master-B cv. during 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).

On the same time, alley cropping of pea with *Sesbania* or *Leucaena* and sole plants inoculated with *Rhizobium* had statistical significant effect on the seeds weight/pod (g). Growing pea with *Sesbania*+1/2 RD of N had a remarkable increment on seeds weight/pod. Generally, it is noticed that there was an increase in this trait in the first season by supplying *Rhizobium* or alley treatments on pea seeds weight compared to the second one (Fig. 2 C and D).

Average weight of 100 seeds

Overall, it is noticed that there were highly significant differences among alley cropping treatments in both seasons for the weight of 100 seeds. Planting pea and *Sesbania* or *Leucaena* plus half of the recommended N fertilization gave the highest weight of 100 seeds compared to the other alley cropping treatments (Fig. 3 A and B). However, the lowest values of this trait due to sowing pea plants between *Leucaena* rows without nitrogen fertilization in the two seasons. On the other hand, *Rhizobium* treatment increased the weight of 100 seeds of the sole pea plants in the second season, but the increment was not significant compared with control plants which received the RD of nitrogen fertilization.

Average fresh weight of pod, pod length and diameter

Obtained data in Figure (4) illustrates the effect of alley pea cropping with *Sesbania* or *Leucaena* trees on the fresh weight of pod (g), pod length (cm) and pod diameter (cm) of pea plants during the two studied seasons. The pod fresh weight became significantly heavier in the second season by *Rhizobium* treatment in comparison with that of the control. As far as alley cropping is concerned, these treatments caused significant differences in pod fresh weight in the two seasons. The increase in pod fresh weight was noticed as a result of planting pea plants with *Sesbania* or *Leucaena*+1/2 RD of N compared to the other alley treatments (Fig. 3 A and B).

Pod length of pea plants (Fig. 3 C and D) followed the same trend like that of the fresh weight of pod. Moreover, the differences between treatments were highly significant. Pod length was significantly increased as a result of *Rhizobium* treatment in comparison with that of control. Regarding the influence of alley cropping treatments it was shown that plants allied with *Sesbania* or *Leucaena*+1/2 RD of N had the highest value compared to the other treatments, in the two seasons of the experiment. It is obvious that there is a significant difference between the means of treatments at the second season only for the pod diameter. However, the thickest pod of pea was produced by plants that received *Rhizobium* before sowing compared to control (recommended N fertilization). Again the pod diameters increased with *Sesbania* or *Leucaena*+1/2 RD of N compared with those resulted from the other alley treatments (Fig. 3 E and F).

Chemical constituents of green seeds

Nitrate (NO_3) and nitrite (NO_2) content

The effect of alley cropping system with *Sesbania* or *Leucaena* trees on the NO_3 content in the fresh seeds of pea plants during 2012 and 2013 seasons is shown in Figure 5 (A and B). The differences among alley cropping treatments under the different levels of nitrogen fertilization were not significant in both seasons. However, the lowest value of NO_3 content was due to alley pea with *Leucaena* only compared to that of the other agroforestry treatments. On the other hand, the differences between *Rhizobium* and the recommended N fertilization on NO_3 content were significant only in the second season. However, the lowest value of NO_3 was due to applying *Rhizobium* on the pea seeds compared to the control. Moreover, supplying *Rhizobium* treatment for pea seeds resulted in the lowest value of NO_2 content compared to the control in both seasons (Fig. 5 C and D). Generally, it is noticed that there were significant differences between alley cropping treatments in this trait in the two seasons. The lowest value of NO_2 content due to sowing pea plants in between *Sesbania* trees without any N fertilization for both seasons compared to the other alley cropping treatments and control.

Protein and carbohydrates percentages

Pea plants which allied with *Sesbania*+1/2 RD of N gave the highest protein % in seeds followed by *Leucaena*+1/2 RD of N and *Sesbania* or *Leucaena*+1/4 RD of N compared with control treatment in both studied seasons (Fig. 6 A and B). Sole pea plants which inoculated with *Rhizobium* had the lowest protein percentage in seeds and that was not significantly different from pea plants which allied with *Sesbania* or *Leucaena* without any nitrogen fertilization.

Data presented in (Fig. 6 C and D) showed that in the both seasons growing pea with *Sesbania* or *Leucaena* increased total carbohydrate in seeds and it was not significantly different from sole pea plants which inoculated with *Rhizobium*, whereas control plants gave the lowest values of total carbohydrate in seeds. The highest percentage was for plants allied with *Sesbania* without nitrogen fertilization (19.35 and 19.81%).

Land equivalent ratio (LER)

The land equivalent ratio (LER) in alley pea system with *Sesbania* or *Leucaena* trees showed that this system had better seed yield performance when compared to sole cropping (Fig. 7 A and B). Pea growing with *Leucaena*+1/2 RD of N had the highest LER in the first season (1.377) while LER increased in pea allied with *Sesbania*+1/2 RD of N in the second season (1.195).

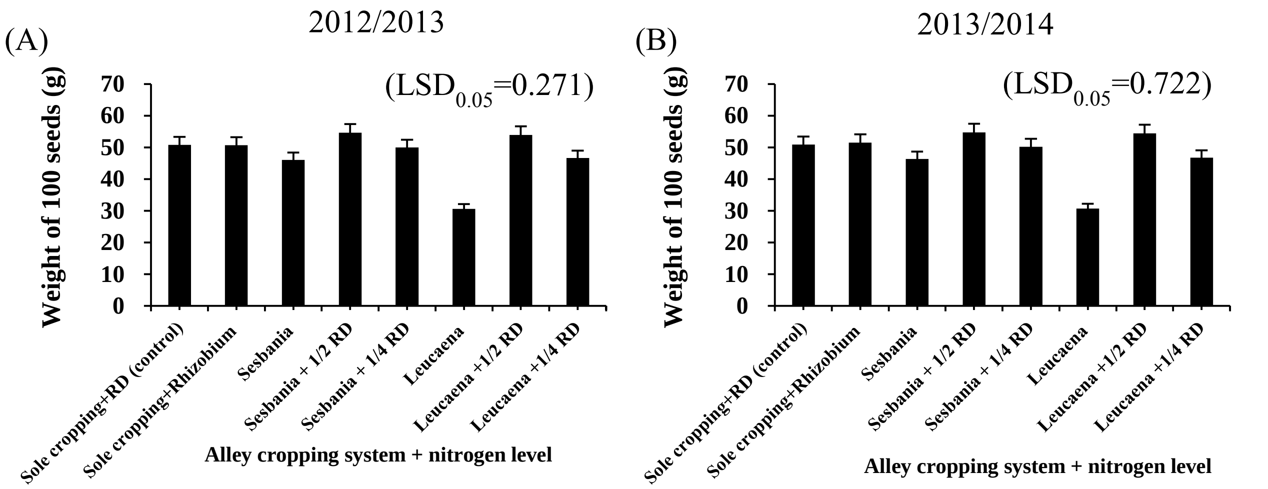

Fig. 3 Effect of alley cropping system with *S. sesban* or *L. leucocephala* under different levels of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose “RD”) and sole plants inoculated with *Rhizobium* on weight of 100 seed (g) of pea plants; Master-B cv. during two successive 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).

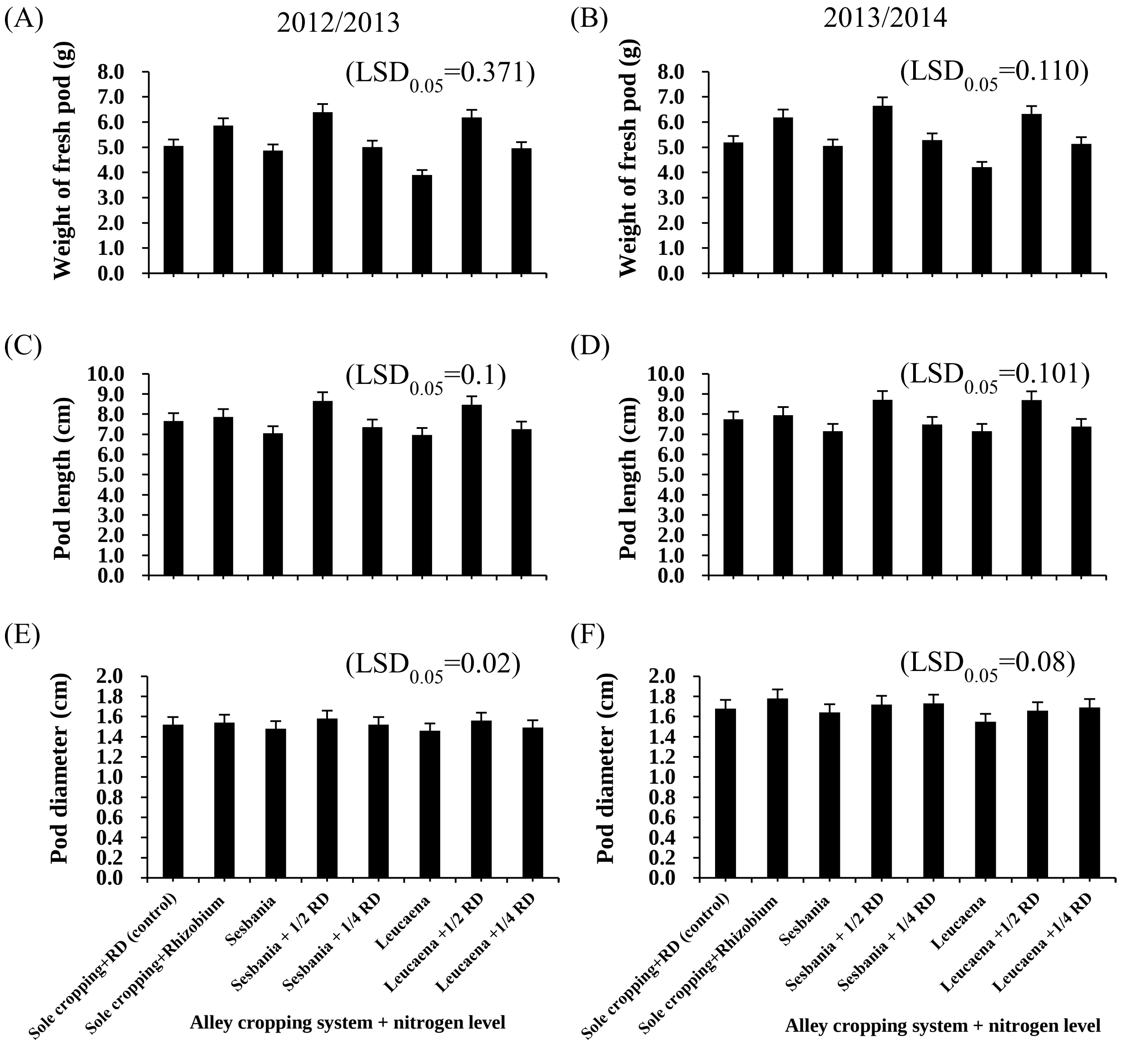

Fig. 4 Effect of alley cropping system with *S. sesban* or *L. leucocephala* under different levels of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose “RD”) and sole plants inoculated with *Rhizobium* on weight of fresh pod (g), pod length (cm) and pod diameter (cm) of pea plants; Master-B cv. during two successive seasons; 2012/2013 (A, C and E) and 2013/2014 (B, D and F), respectively. Control sole pea plants received 50 kg/fed ammonium sulfate+100 kg/fed ammonium nitrate as recommended N dose (RD).

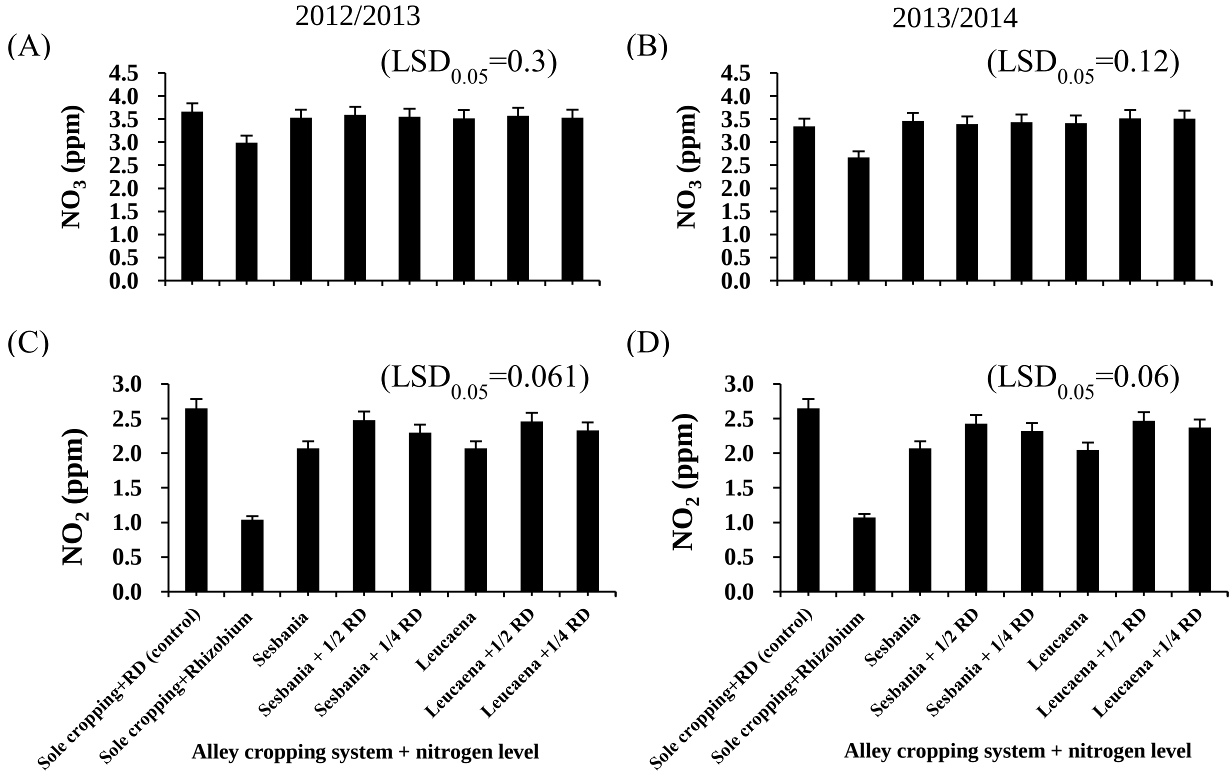

Fig. 5 Effect of alley cropping system with *S. sesban* or *L. leucocephala* under different levels of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose "RD") and sole plants inoculated with *Rhizobium* on NO_3 (A and B) and NO_2 (C and D) contents in the fresh seeds of pea plants; 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).

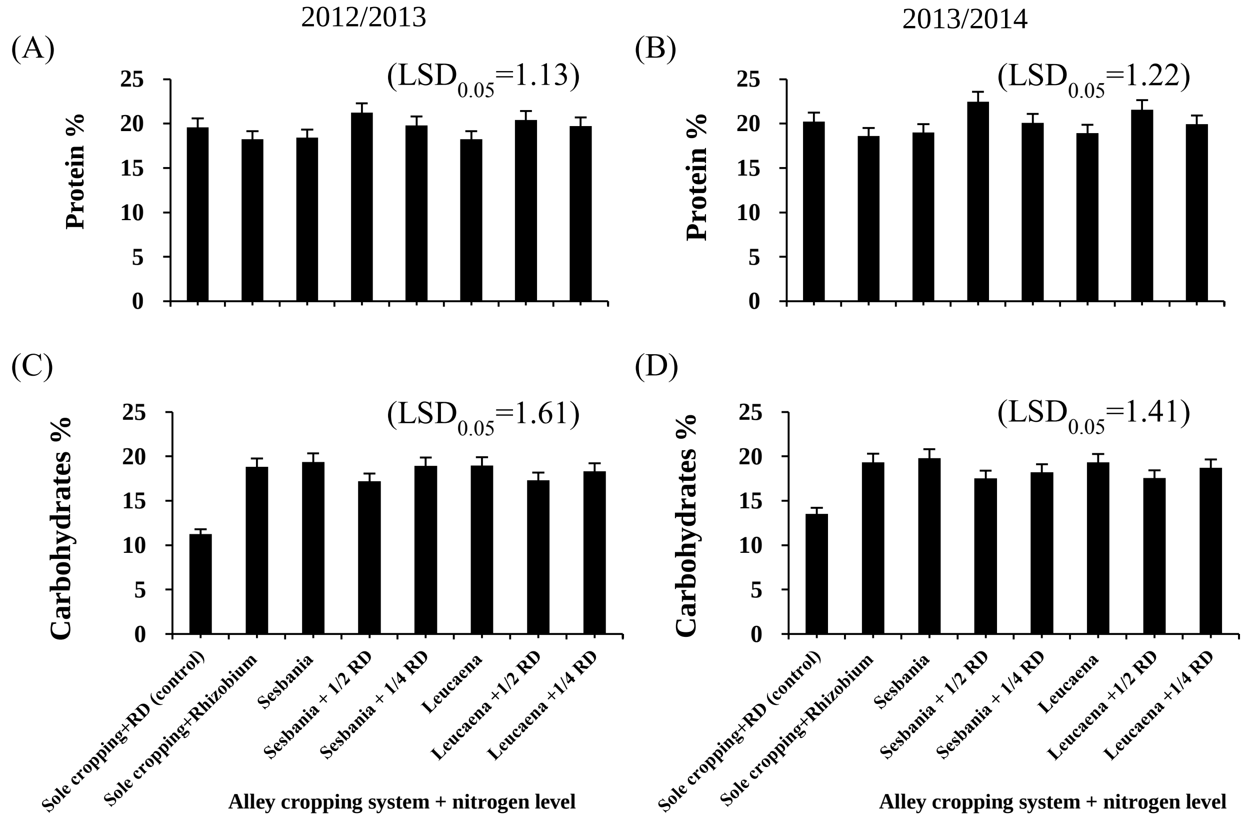

Fig. 6 Effect of alley cropping system with *S. sesban* or *L. leucocephala* under different levels of nitrogen fertilization in-row (0, 1/4 and 1/2 of the recommended N dose "RD") and sole plants inoculated with *Rhizobium* on protein % (A and B) and carbohydrates % (C and D) in the fresh seeds of pea 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).

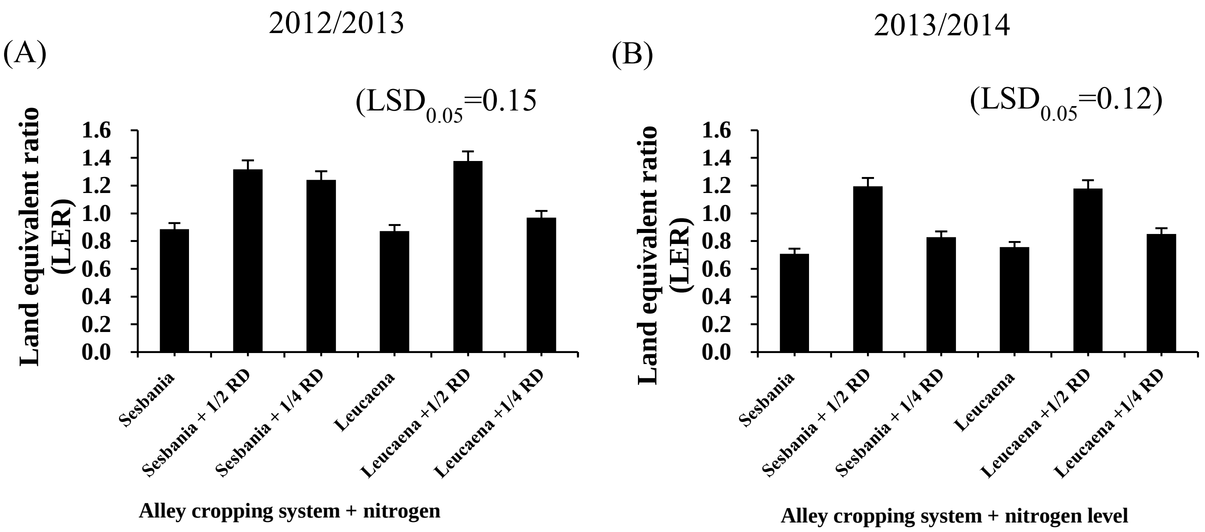

Fig. 7 Land equivalent ratio (LER) of pea plants allied with *S. sesban* or *L. leucocephala* during two successive seasons; 2012/2013 (A) and 2013/2014 (B), respectively. When LER values are higher than 1, it means that there is an advantage of alley cropping in terms of the use of resources for the plant growth compared to sole cropping. When LER values are lower than 1, it means that sole cropping use the resources more efficiently in comparison with alley cropping system.

DISCUSSION

Peas usually require cool temperature. Bloom generally occurs about 60 days after seeding and maturity occurs at about 90 days. High temperatures during flowering (>32.3º C) can cause flowers to blast, and reduces seed yield. Pea respond well to good moisture at emergence until bloom, then dry, warm weather for pod filling and ripening (Oelke *et al*., 1991; Desphande and Adsule, 1998). Integration in an alley cropping system appears to be viable practices as these systems not only addresses production function but also help to abate some of the environmental problems such as high temperature, soil erosion, low fertility (Lawson and Kang, 1990; Lai, 1991). Significant amounts of biological fixed N can be achieved in many levels of agricultural and leguminous trees. It is evident from this field study that growing the common vegetable pea, alongside legume trees *Sesbania* and *Leucaena*, in a common agroforestry system increased vegetative growth, nodulation status and chemical composition (Zaki *et al*., 2016), yield due to the symbiotic relationship between rhizobia bacteria and its ability to fix nitrogen within the nodules formed on legume roots (Halliday and Somasegaran, 1983; Okogun *et al*., 2000). *Sesbania* and *Leucaena* are extremely versatile plants which have significant contribution to production, weed control, firewood source to the subsistence crop-livestock mixed farming system (Isaac *et al*., 2003; Ebeid *et al*., 2015).

The yield and yield attributes of pea were differed under different alley cropping treatments. However, the highest values of the yield and seed parameters were noticed with *Sesbania* or *Leucaena*+1/2 RD. Also, the lowest values of these characters were recorded with pea plants that planted between *Sesbania* or *Leucaena* trees only. Therefore, it might be practical to apply some N-fertilizer to the allied crop in the alley system. These results were in accordance with that of many researchers (Olasantan, 2000 and Ebeid *et al.*, 2015). Substantial amounts of inorganic N as well as N-rich organic materials from legume trees are needed to make a significant impact on crop yields (Giller *et al*., 1997). Thus, it appears that N fertilization as the key factor in defining the productivity and sustainability of our alley cropping systems in Aswan, Egypt. The current study 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 pea crop, and are capable of retrieving nutrients and water from sub-soil beyond the rooting depth of annual crops. Further, with annual pruning and periodic thinning to create high-value timber, light or moisture may never become a significant limiting factor in this system. In practice, this system could maintain pea yield and seed quality at high levels under the high temperature of Aswan, but farmers have a number of traditional practices that could be utilized, including annual pruning and moderate level of fertilization.

CONCLUSION

Growing pea under alley cropping system contributes to improve yield and seed quality. Also, this contribution reduced the dependence on mineral fertilizer-N. Moderate quantities of mineral fertilizer-N combined with legume trees had improved the pea yield. It can be concluded that growing pea and *Sesbania* or *Leucaena* +1/2 RD of N can result in an environment around the crop achieving higher LER which translates to better seed yield compared to the sole pea plants.

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