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Role of soil fertility management on productivity of sesame and cowpea under different cropping systems

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ABSTRACT- Declining land productivity associated with decreasing soil organic carbon and nutrients is a significant issue in monoculture production. The field experiment with different rates of fertilizer systems (60 kg ha^{-1} N + 100 kg ha^{-1} P, 300 kg ha^{-1} Bio-organic (organic fertilizer), 3 kg ha^{-1} Bioumik (biofertilizer), 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic fertilizer and 30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik) as main effects and five cropping systems (sole sesame, sole cowpea, 50:50 sesame-cowpea intercropping, 75:25 sesame-cowpea intercropping and 25:75 sesame-cowpea intercropping) as subplot effects were carried out to study the influence of fertilizer systems application on productivity in intercrops and monocultures. Intercropping of 50:50 sesame-cowpea compared to monoculture plots was highly productive in terms of land equivalent ratio (1.03), area time equivalent ratio (1.04) and land use efficiency (155%). Across fertilizer systems, the greater values of land equivalent ratio (1.24), area time equivalent ratio (1.25) and land use efficiency (186%) were obtained from 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic. The results indicate that fertilizer application rate of 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic and intercropping of 50:50 sesame-cowpea could be an effective pathway in raising of productivity toward sustainable agriculture through maximum exploitation of the biological potential for efficient acquisition of P, N and other resources.

INTRODUCTION

Soil organic matter plays a key role in the improvement of soil physical, chemical and biological properties (Oue´draogo et al., 2007). Organic manure and inorganic fertilizer are the most common materials applied in agricultural management to improve soil quality and crop productivity (Verma and Sharma, 2007). The use of organic amendments in agriculture has increased over the years, due to the increasing cost of inorganic (chemical) fertilizers and high demand for quality and uncontaminated products (Sangakkara, 1993). The application of organic fertilizers is a major component of organic farming practices (Berner et al., 2008). Organic manures can provide the essential plant nutrients and enhance crop productivity, but also leave a beneficial residual effect on succeeding crops (Ghosh et al., 2004). Organic manure improves soil tilth, infiltration rate and soil water holding capacity, contributes nutrient to the crop and is an important source of raw or partially decomposed organic matter (Bill, 2001). Jannoura et al. (2014) have found that application of C-rich organic fertilizers, such as yard-waste compost, but especially horse manure, greatly stimulated soil microbial biomass indices, which was reflected by increased yield.

Farmers practice different cropping systems to increase productivity and sustainability (Hauggaard-Nieson et al., 2001). Intercropping increases total productivity per unit area through maximum utilization of land, labour and growth resources (Marshal and Willy, 1983). Plants may ameliorate harsh environmental conditions or increase the availability of resources for other species (Lambers et al., 1998). Yields of intercropping are often higher than in sole cropping systems (Lithourgidis et al., 2006) mainly due to resources such as water, light and nutrients that can be utilized more effectively than in sole cropping systems (Li et al., 2006). When including legumes in an intercrop system, the symbiotic N_2 fixation and residue incorporation also contribute to ameliorating soil fertility (Jensen, 1996). Legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and be used by other plants growing nearby (Andrews, 1979). Furthermore, implementation of intercrops in agroecosystems has been shown to increase diversity of microbes, flora and fauna, which often have a positive impact on crop productivity (Vandermeer, 1995). Interspecific belowground interactions and rhizosphere effects between intercropped species played an important role in yield advantage of intercropping (Zhang and Li, 2003). Geno and Geno (2001) concluded that interspecific competition and facilitation occurs at the same time. Vandermeer (1989) noted that both competition and facilitation take place in many intercropping systems, and that it is possible to obtain the net result of land equivalent ratio (LER), an indicator of intercropping advantage, >1 where the complementary facilitation is contributing more to the interaction than the competitive interference. Thus, an LER>1 could result from low interspecific competition or strong facilitation.

Sesame (*Sesamum indicum* L.) is one of the oldest domesticated oilseed crops. Due to the presence of high oil, protein and other nutritional elements, its seed has become an important ingredient of food and feed (Najeeb et al., 2012). The crop is generally adapted to tropical regions of world, where it is mainly grown for edible seeds and oil (Weiss, 2000). Cowpea (*Vigna unguiculata* L.) is a widely adapted, stress tolerant grain legume, vegetable, and fodder crop grown in warm to hot regions of Africa, Asia, and the Americas (Ehlers and Hall, 1997). The ability of cowpea plant to tolerate drought and poor soil makes it an important crop in the regions where these constraints restrict other crops. Amongst other advantages, cowpea may benefit from an efficient N_2–fixing symbiosis. Its grain is nutritious and is a cheap source of protein for both rural and urban consumers. In view of the above, the objective of the present study was to test the hypothesis that intercropping suitable crop combinations at a rational fertilizer application rate will maximize productivity by interspecific interactions in the quest toward sustainable and productive sesame-cowpea intercropping systems under field conditions.

MATERIALS AND METHODS

The field experiment, during 2014, was carried out at research farm in Fasa region, Fars province, Iran, located between 28°32´ N and 54°15´ E with an elevation of about 1450 m above mean sea level. The experimental site classified as semi-arid climate, with an average annual temperature and rainfall of about 20.3 C° and 301.7 mm, respectively. The soil of the experimental site was silty-loam in texture with pH 7.9.

Treatment and Experimental Details

Research plots were arranged as a split plot based on randomized complete block design (RCBD) with twenty five treatments. The field experiments with different rates of fertilizer systems (60 kg ha^{-1} N + 100 kg ha^{-1} P (F1), 300 kg ha^{-1} Bio-organic (F2) (an organic fertilizer with base of compost that for easier use became a granular), 3 kg ha^{-1} Bioumik (F3) (a biofertilizer containing some microorganisms such as symbiotic and non-symbiotic nitrogen-fixing bacteria of the genus Rhizobium, Azotobacter and Azospirillum, phosphate solubilizing bacteria and a bacteria of the genus Pseudomonas and Bacillus), 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic fertilizer (F4) and 30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik (F5)) as main effects and five cropping systems (sole sesame (M1), sole cowpea (M2), 50:50 sesame-cowpea intercropping (M3), 75:25 sesame-cowpea intercropping (M4) and 25:75 sesame-cowpea intercropping (M5)) as subplot effects were carried out to study the influence of fertilizer systems application on productivity in intercrops and monocultures. In monocultures, sesame and cowpea were planted in rows at the recommended plant density targeting 30 and 20 plants m^{-2}, respectively. The intercropping treatments consisted of planting sesame and cowpea in alternate rows (1:1 arrangement) in proportional replacement design in which the combined density of the population varied as the proportions of the species changed. At least 50 cm was kept between each plot to minimize treatment interactions, and 1 m between each block to facilitate plot management. Nitrogen (N) from urea and phosphorus (P) from triple superphosphate sources were supplied. Bioumik biofertilizer (in water soluble form) and Nitrogen, were applied 40 days after planting and phosphorus and Bio-organic fertilizer were applied at planting time. The seeds were planted on 29 June 2014. Sowing depth varied with seed size and ranged from 1–2 cm for sesame to 4–5 cm for cowpea. The experiment was conducted in irrigated condition and weeding and hoeing were done when required.

Data Collection and Productivity Assessment

At harvest time (14 November 2014), plant height, number of branches per plant, number of pods per plant, number of seeds per pod, seed and biological yield of cowpea and plant height, number of capsules per plant, number of branches per plant, seed and biological yield of sesame were recorded. Shoots of sesame and cowpea plants were harvested by hand above soil level leaving about 5 cm stubble, dried and weighed separately. Individual crop yield (grain and shoot biomass) was calculated to permit comparison of yields and land equivalent ratios (LER) with those when they were grown alone. System productivity was estimated using the land equivalent ratio (LER) which compares the yield obtained by intercropping two or more species together with yields obtained by growing the same crops as monocultures. The LER for two intercrop species in proportional replacement design were calculated by equation 1 as follows (Mead and Willey, 1980):

$$\text{LER}=\frac{Yab}{Yaa}+\frac{Yba}{Ybb} \qquad (1)$$

where *Yaa* and *Ybb* are the yield of crop a and b in sole cropping. *Yab* and *Yba* are yield of crop *a* and *b* in intercropping. The yields of mono and intercrop species were calculated as kg ha^{-1}. Intercropped plots with LER values greater than 1.0 produced a yield advantage while plots with values less than 1.0 showed a yield disadvantage. LER in terms of total plant mass (grain + shoot biomass) production was determined. The other indices to estimate system productivity, Area time equivalent ratio (ATER) and Land use efficiency (LUE) were calculated using equations 2 and 3 developed by Mead and Willey (1980).

$$\text{ATER}=(Yab+\frac{ta}{Yaa})+(\frac{Yba\times(tb/Ybb)}{t}) \qquad (2)$$

$$\text{LUE}=(LER+\frac{ATER}{2})\times 100 \qquad (3)$$

Where *ta* and *tb* are the duration (days) of crop *a* and *b* in intercropping and *t* is the total duration (days) of intercropping system.

Statistical Analysis

The data recorded were statistically analyzed using the procedure of SAS 9.1. Critical difference (CD) values at 5% level of probability were calculated for comparing the treatment means (using Duncan test).

RESULTS AND DISCUSSION

Yield and Yield Attributes of Sesame

Yield and yield components of sesame are shown in Table 1. Across fertilizer rates, total dry matter significantly increased in application of 300 kg ha^{-1} Bio-organic fertilizer with an average of 3482.62 kg ha^{-1}, seed yield in application of 300 kg ha^{-1} Bio-organic fertilizer with an average of 950.49 kg ha^{-1} was significantly higher than other treatments. Maybe increasing in yield by application of organic fertilizer can be attributed to more optimum plant growth conditions. It has been reported that organic manures can provide the essential plant nutrients and enhance crop productivity, but also leave a beneficial residual effect on succeeding crops (Ghosh et al., 2004). It is possible that the yield increased due to higher photosynthetic rate and biomass production under application of organic fertilizers. Under field conditions, significant and positive correlations between leaf photosynthesis and crop yields have been reported for some crops, such as soybean (Ghosh et al., 2006), sorghum (Peng et al., 1991), and sweet corn (Efthimiadou et al., 2009). Also, in some crops, it has been reported that manure and compost increased the average photosynthetic rate (Liu et al., 2004; Antolín et al., 2010; Jannoura et al., 2014). Jannoura et al. (2014) have also reported the positive effects of organic fertilizers on growth and yield increase of pea and oat. The highest plant height obtained from application of 3 kg ha^{-1} Bioumik, number of capsules per plant were highest in application of 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic fertilizer which is statistically listed into one group with F3 and F5 treatments and the number of branch was maximum in application of 60 kg/ha N + 100 kg/ha P. Non-symbiotic nitrogen fixing bacteria such as: Azotobacter chroococcum and Azospirillum lipoferum were found to have not only the ability to fix nitrogen but also release phytohormones similar to gibberellic acid and indole acetic acid, which could stimulate plant growth, absorption of nutrients, and photosynthesis (El Ghadban et al., 2006; Mahfouz and Sharaf Eldin, 2007). The results of Akhani et al. (2012) in coriander have indicated that plant height was significantly affected by the application of biofertilizer (nitrogen fixing bacteria).

It seems that integrated applications of inorganic and organic fertilizers by increasing soil fertility and supplying plant nutrient requirements and as a result, producing more photosynthetic substances increased the production of capsules per plant. Many studies have shown that the balanced application of inorganic fertilizers or organic manure plus inorganic fertilizers can increase soil organic carbon and maintain soil productivity (Blair et al., 2006; Powlson et al., 2012). Also, according to the results, it seems that there is a direct relationship between plant height and the number of branches because by reducing plant height, the number of branches increased. Across cropping systems, total dry matter, seed yield, number of capsules per plant and plant height in sole sesame were significantly higher than in intercropping systems; the number of branches significantly increased in 50:50 sesame-cowpea intercropping (Table 1). Less total dry matter and seed yield in intercropping systems compared to sesame sole cropping probably were due to the decreased density of sesame per unit area. It is clear that changes in yield components (an increase in the number of branches and a decrease in the number of capsules) in intercropping systems failed to compensate for the effect of density reduction on yield. The result is in agreement with that obtained by Pouramir et al. (2010) who found that the yield of sole sesame was significantly higher than that of intercropping treatments.

Cowpea Yield and Dependent Traits on Yield

Cowpea yield and dependent traits on yield are shown in Table 2. The total dry matter and seed yield of cowpea were influenced by fertilizer rates and different cropping systems. The total dry matter and seed yield increased significantly with an average of 2982.50 and 7056.56 kg ha^{-1} in application 3 kg ha^{-1} Bioumik biofertilizer (the seed yield was listed statistically in one group with application of 30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik biofertilizer) (Table 2). Increased yield using growth promoting bacteria as a biofertilizer in some crops such as common bean (Isvand et al., 2014), chickpea (Valverde et al., 2006) and mung bean (Ahmad et al., 2012) has been reported. The maximum number of pods per plant was obtained from application of 30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik. The results of Aminifar et al. (2013) in soybean have also showed that the number of pods per plant is the most important trait on yield production. According to the results, it seems that there is a direct relationship between plant height and the number of branches because by increasing plant height, the number of branches decreased (Table 2). Among cropping systems, the total dry matter and seed yield were significantly higher in sole cowpea than in all intercropping systems (Table 2) which is probably due to a reduction in cowpea density in intercropping systems. The highest number of pods and branches per plant were obtained from sole cowpea as well. Maybe these two traits have a significant effect on cowpea yields.

Table 1. Yield and yield components of sesame as affected by fertilizer rates and cropping systems

Fertilizer rates	Plant height (Cm)	Number of capsules per plant	Number of branches per plant	Seed yield (Kg Ha^{-1})	Total dry matter (Kg Ha^{-1})
F1	58.49 e	15.91 c	3.07 a	800.80 b	2941.45 b
F2	63.69 c	16.99 b	2.49 b	950.49 a	3482.62 a
F3	70.24 a	18.41 a	2.33 c	782.29 b	2805.15 c
F4	65.98 b	18.49 a	2.55 b	670.96 d	2433.58 e
F5	60.65 d	18.16 a	2.08 d	711.06 c	2551.73 d
Cropping systems					
M1	71.21a	20.39a	1.99c	1292.60a	4691.04a
M3	61.22c	16.26c	2.93a	648.27c	2358.87c
M4	60.56d	17.46b	2.52b	885.21b	3220.25b
M5	62.25b	16.26c	2.57b	306.40d	1101.46d

Different letters in each columns indicate a significant difference according to the Duncan test ($P < 0.05$).
F1, F2, F3, F4 and F5 are 60 kg ha^{-1} N + 100 kg ha^{-1} P, 300 kg ha^{-1} Bio-organic fertilizer (organic fertilizer), 3 kg ha^{-1} Bioumik (biofertilizer), 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic fertilizer and 30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik, respectively. M1, M3, M4, M5 are sole sesame, 50:50 sesame-cowpea intercropping, 75:25 sesame-cowpea intercropping and 25:75 sesame-cowpea intercropping, respectively.

Table 2. Yield and yield components of cowpea as affected by fertilizer rates and cropping systems

Fertilizer rates	Plant height (cm)	Number of branches per plant	Number of pods per plant	Number of seeds per pod	Seed Yield (kg ha^{-1})	Total dry matter (kg ha^{-1})
F1	60.74 d	2.08 b	7.91 c	10.06 b	1518.63 d	3683.59 e
F2	66.49 c	2.08 b	7.08 d	7.71 e	2010.05 b	4791.50 c
F3	73.16 b	2.74 a	11.16 b	9.91 c	2982.50 a	7056.56 a
F4	116.3 a	1.49 d	7.66 c	10.33 a	1754.51 c	4451.39 d
F5	67.99 c	2.07 c	11.58 a	9.73 d	2872.06 a	6719.44 b
Cropping systems						
M2	60.29d	2.61a	9.59a	9.73b	3772.40a	9179.20a
M3	73.73c	2.08b	9.26b	9.87a	1666.60c	3926.40c
M4	91.56a	1.94c	9.26b	9.28d	961.20d	2296.40d
M5	82.19b	1.74d	8.19c	9.31c	2510.00b	5960.00b

Different letters in each columns indicate a significant difference according to the Duncan test ($P < 0.05$).
F1, F2, F3, F4 and F5 are 60 kg ha^{-1} N + 100 kg ha^{-1} P, 300 kg ha^{-1} Bio-organic fertilizer (organic fertilizer), 3 kg ha^{-1} Bioumik (biofertilizer), 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic fertilizer and 30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik, respectively. M1, M3, M4, M5 are sole sesame, 50:50 sesame-cowpea intercropping, 75:25 sesame-cowpea ntercropping and 25:75 sesame-cowpea intercropping, respectively.

Land Equivalent Ratio (LER)

LERs were calculated for intercropping and fertilizer treatments to determine any advantage to be realized from the intercropping and fertilizer management. The results showed that the intercropping of sesame and cowpea was more productive than sole cropping of either species. The largest LER (1.03) was obtained from the 50:50 sesame-cowpea intercropping (Table 3). The greater value of LER with 50:50 sesame-cowpea intercropping was due to higher relative yield of component crops. The highest LER in different fertilizer rates was obtained from 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic (LER = 1.24) followed by 60 kg ha^{-1} N + 100 kg ha^{-1} P (LER = 1.09) (Table 3).

Area Time Equivalent Ratio (ATER)

ATERs were calculated for intercropping and fertilizer treatments to determine yield advantage in relation to time and is presented in Table 3. ATER values were also highest in 50:50 sesame-cowpea intercropping system (1.04) and 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic system (1.25).

Land Use Efficiency (LUE)

Land use efficiency calculated for intercropping and fertilizer treatments (Table 3) had a similar trend as those of LER and ATER. Maximum LUE values were recorded in 50:50 sesame-cowpea intercropping system (155) and 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic (186). This indicates that intercropping of 50:50 sesame-cowpea and application of 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic were found to be highly efficient.

Table 3. Land equivalent ratio (LER), area time equivalent ratio (ATER) and land use efficiency (LUE) in different fertilizer rates and cropping systems.

Fertilizer rates	LER	ATER	LUE%
60 kg ha^{-1} N + 100 kg ha^{-1} P	1.09	1.1	163
300 kg ha^{-1} Bio-organic (organic fertilizer)	0.78	0.79	117
3 kg ha^{-1} Bioumik (biofertilizer)	0.83	0.84	124
30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic	1.24	1.25	186
30 kg ha^{-1} N + 50 kg ha^{-1} P + 1.5 kg ha^{-1} Bioumik	0.83	0.84	125
Cropping systems			
50:50 sesame-cowpea intercropping	1.03	1.04	155
75:25 sesame-cowpea intercropping	0.978	0.98	147
25:75 sesame-cowpea intercropping	0.976	0.98	146

An intercropping system combining sesame and cowpea and soil fertility management may help increase land productivity as well as maintain soil organic carbon and soil minerals. The present study supports the hypothesis that intercropping systems are advantageous over sole cropping in terms of yield because as the results showed, the productivity of intercropping components was significantly higher in intercropping than that of sole cropping which can be attributed to facilitative interactions in intercropping systems. Intercropping of 50:50 sesame-cowpea compared to monoculture plots was highly productive in terms of land equivalent ratio (1.03), area time equivalent ratio (1.04) and land use efficiency (155%). Yaseen et al. (2014) have also reported that intercropping compared to sole cropping was highly productive in terms of land equivalent ratio (LER), area time equivalent ratio (ATER) and land use efficiency (LUE). However, the degree of success varied greatly with the growing conditions and the proportion of species used in the field (Jensen, 1996; Lauk and Lauk, 2008; Hauggaard-Nielsen et al., 2009).

In general, these results indicate that 50:50 sesame-cowpea intercropping can be recommended as effective crop combinations to increase productivity by exploiting the biological potential of crops in intercropping systems. Complementarity and facilitation in resource use (e.g. light, water and soil nutrients) between sesame and cowpea may explain the increase in yields. Complementarity may be defined as a decline in interaction or a decrease in interspecific competition or competitive exclusion due to differences and complementarity in species traits related to resource foraging (Tilman, 1982). Species may use resources differently in time, space, and forms (Fridley, 2001). In relation to soil nutrients and water, spatial complementarity can occur between two species by contrasting root architecture to explore different soil horizons, and/or because of the plasticity of root systems, combined with possible avoidance strategies (Hauggaard-Nielsen and Jensen, 2005; DE Kroon, 2007). In addition, intercropped species may exhibit contrasting phenologies (Rose et al., 2007) and/or growth periodicity due to different sowing and harvest dates, which may result in temporal niche complementarity showing differential requirements of N, P and some other nutrients over time and increasing their availability by mineralization of the residues of the earlier maturing crop (Li et al., 1999; Li et al., 2007).

Li et al. (2006) have showed that root compatibility between intercropped maize and associated faba bean may allow the intercropped maize to spread underneath the roots of neighbors and intermingle with them, thereby increasing root length density, root growth space and corresponding nutrient and water uptake. The results of the experiment also showed that in order to achiev the aims of sustainable agriculture and reduce the application of chemical fertilizers, the organic fertilizer (Bio-organic) not only compensated for the effectiveness of chemical fertilizer on yield but also increased that significantly. Across fertilizer systems, the greater values of land equivalent ratio (1.24), area time equivalent ratio (1.25) and land use efficiency (186%) were obtained from 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic. As organic fertilization is an important means for improving soil fertility and makes the farming systems more sustainable; therefore, it seems that integrated applications of inorganic and organic fertilizers provide the essential plant nutrients and as a result, enhance system productivity. The results of Xia et al. (2013) have also indicated that the intercropping system and a rational fertilizer application rate maintained maximum total grain production.

CONCLUSIONS

Interspecific interactions enhanced yield in 50:50 sesame-cowpea intercropping system. The higher yield was ascribed to interspecific interactions between intercropped species, including interspecific niche complementarity and facilitation in better use of light, water and other resources. It seems that a rational fertilizer application rate (e.g. 30 kg ha^{-1} N + 50 kg ha^{-1} P + 150 kg ha^{-1} Bio-organic) in intercropping systems can maintain higher crop yields. Therefore, the intercropping of 50:50 sesame-cowpea with a rational fertilizer application rate could be an important pathway toward sustainable and productive agriculture.

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نقش مدیریت حاصلخیزی خاک بر قابلیت تولید کنجد و لوبیا چشم بلبلی تحت شرایط سیستم‌های مختلف کاشت

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چکیده- کاهش باروری زمین‌های کشاورزی مرتبط با کاهش مواد آلی خاک و عناصر غذایی، موضوعی مهم در سیستم‌های تک‌کشتی می‌باشد. سیستم مخلوط کنجد و لوبیا چشم بلبلی و مدیریت حاصلخیزی خاک می‌تواند کمک به افزایش باروری زمین و همچنین حفظ مواد آلی و عناصر غذای خاک، کند. در همین راستا آزمایشی با مقادیر مختلف کود (۶۰ کیلوگرم نیتروژن+۱۰۰کیلوگرم فسفر، ۳۰۰ کیلوگرم کود آلی بیوارگانیک، ۳ کیلوگرم کود زیستی بیومیک، ۳۰ کیلوگرم نیتروژن+۵۰ کیلوگرم فسفر+۱۵۰ کیلوگرم کود آلی بیوارگانیک، ۳۰ کیلوگرم نیتروژن+۵۰ کیلوگرم فسفر+۳ کیلوگرم کود زیستی بیومیک) به عنوان عامل اصلی و سیستم‌های کاشت (کنجد، لوبیا چشم بلبلی، ۵۰:۵۰ کنجد-لوبیاچشم بلبلی، ۲۵:۷۵ کنجد-لوبیا چشم بلبلی، ۷۵:۲۵ کنجد-لوبیا چشم بلبلی) به عنوان عامل فرعی به منظور بررسی اثر سیستم‌های کودی بر قابلیت تولید کشت مخلوط و تک‌کشتی، انجام شد. کشت مخلوط ۵۰:۵۰ کنجد-لوبیا چشم بلبلی در مقایسه با تک کشتی‌ها از نظر شاخص‌های نسبت برابری زمین (۱/۰۳)، نسبت برابری زمان زمین (۱/۰۴) و کارایی استفاده از زمین (۱۵۵٪)، از سودمندی بالاتری برخوردار بودند. در بین سیستم‌های کودی نیز بالاترین مقادیر نسبت برابری زمین (۱/۲۴)، نسبت برابری زمان زمین (۱/۲۵) و کارایی استفاده از زمین (۱۸۶٪) متعلق به سیستم کودی ۳۰ کیلوگرم نیتروژن+۵۰ کیلوگرم فسفر+۱۵۰ کیلوگرم کود آلی بیوارگانیک بود. به طور کلی نتایج نشان داد که کاربرد ۳۰ کیلوگرم نیتروژن+۵۰ کیلوگرم فسفر+۱۵۰ کیلوگرم کود آلی بیوارگانیک و سیستم مخلوط ۵۰:۵۰ کنجد و لوبیا چشم بلبلی می‌تواند رویکردی مؤثر در افزایش بهره‌وری در راستای کشاورزی پایدار از طریق بهره‌گیری از پتانسیل بیولوژیکی برای استفاده نیتروژن و فسفر و دیگر منابع، باشد.