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Maximizing Nitrogen and Land Use Efficiencies of Intercropped Wheat with Pea Under Different Pea Sowing Dates

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Abstract: A two – year field trial was conducted with intercropped pea + wheat and sole crops to decrease nitrogen (N) inputs of wheat crop by intercropping with pea and increase farmer's benefit. Average yield of pea + wheat intercrops was greater by growing wheat after 45 days from pea sowing. Application of mineral N fertilizer doses increased grain yield of intercropped wheat, but had non-significant effect on intercropped green pod yield of pea. Land equivalent ratio (LER) and land equivalent coefficient (LEC) values for intercrops were much greater than 1.00 and 0.25, respectively, indicating less land requirements of intercropping systems than sole wheat. As a result of intercropping; yield, N uptake and net returns were improved in intercropped wheat with pea, suggesting the potential of intercropped wheat was increased compared to those of sole wheat.

Keywords: Intercropping, Wheat, Pea Sowing Dates, Mineral N Fertilizer Doses, N Use Efficiency

1. Introduction

Wheat yield is primarily nitrogen (N) – limited under production system in Egypt. Additionally, the requirements for N fertilizer are predicted to increase further in the future [1]. Now, the use of expensive chemical N fertilizers in Egypt is a limiting factor for the low-income farmers and increases the cost of crop production where prices of chemical N fertilizers during a few years have increased. With the current technology for fertilizer production and the inefficient methods employed for fertilizer application, both the economic and ecological costs of fertilizer usage will eventually become prohibitive [2]. Reference [3] reported that application of 100% of the recommended mineral N fertilizer (120 kg/ha) for wheat (*Triticum aestivum* L.) recorded higher grain and straw yields than the 50% of the recommended mineral N fertilizer and the control. Hence, there is an urgent need to maximize the efficient use of this element without excessive use of mineral N fertilizer. N use efficiency (NUE) was originally defined as the dry mass productivity per unit N taken up from soil [4]. Wheat is the most important cereal crop as it is the staple food of the Egyptian people, but the gap between wheat consumption and production is continuously increasing due to steady increase in the human population with limited cultivated area. The total cultivated area of wheat has reached to about 1.3 million ha with an average yield of 6.51 tons per ha [5].

The main target of this research was to increase the net income of Egyptian farmers by using suitable agricultural practices such as intercropping for improving wheat plant efficiency in using mineral N fertilizer through biological N fixation (BNF). Intercropping can result in greater than expected yields because of enhanced use of resources such as nutrients. Pea (*Pisum sativum* L.) a legume crop that played an important role in BNF, because these pea plants were nodulated by *Rhizobium leguminosarum* bv viciae [6]. Importance as of BNF a primary source of N for agriculture had diminished in recent decades as increasing amounts of fertilizer-N have been used for the production of food and cash crops [7]. The efficiency of BNF was influenced by many environmental factors including soil conditions, such as soil type [8] and high N levels [9]. Pea + wheat intercropping was a strategy that used N sources efficiently due to its spatial self-regulating dynamics, where pea improve its inter-specific competitive ability in areas with lower soil N levels, and vice versa for wheat, paving way for future option to reduce N inputs and negative environmental impacts of agricultural crop production [10]. Pea is rich in protein, amino acids, sugars, carbohydrate, vitamins A and C, calcium, phosphorus and a small amount of iron. Pea is mainly grown for green pods and its biomass is also useful as source of N [11]. Reference [12] reported that the success of a pea crop depends on formation of effective N-fixing symbioses with root nodule bacteria and sowing date. He added that sowing pea on 15th October gave the highest dry matter yield (6.34 ton/ha), while it decreased to 1.37 ton per ha by delay in sowing at 30th November. The total cultivated area for pea reached about 17,858 ha with an average yield of 10.09 tons per ha [13].

Accordingly, importance of number of wheat rows/ridge could be related with the suitable dose of mineral N fertilizer that has not a series of impacts on the environment under intercropping conditions. The reduction in mineral N input will increase farmer's benefit by following up yield advantage of each row compared to those of sole wheat. Therefore, the main objective of the present research was to decrease N inputs of wheat crop by intercropping with pea and increase farmer's benefit.

2. Materials and Methods

A two- year study was carried out at Gemmiza Agricultural Experiments and Research Station, A.R.C., El-Gharbia governorate (Lat. 30° 47' 27" N, Long. 30° 59' 53" E, 22 m a.s.l.), Egypt during 2012/2013 and 2013/2014 seasons. Maize was the preceding summer crop in both seasons. The experimental soil had 41.95 % clay, 31.65 % silt, 3.20 % course sand, 23.20 % fine sand and the texture was clay. Chemical analysis of the soil (0 – 30 cm), pH value, available N, available P and available K were analyzed by Water and Soil Research Institute, ARC (Table 1). Methods of mechanical and chemical analysis employed were as described by [14].

Table 1. *Chemical properties of Gemmiza site in 2012 and 2013 seasons before pea sowing.*

Chemical properties	Growing season	
	2012	2013
pH	7.85	7.90
Available N ppm (optimum: 40 – 80)	65.0	70.0
Available P ppm (optimum: 10 – 15)	2.50	3.00
Available K ppm (optimum: 300 – 500)	195.0	210.0

Furrow irrigation was the irrigation system in this study. Calcium super phosphate (15.5% P_2O_5) at rate of 357 kg per ha and potassium sulfate (48.0% K_2O) at rate of 119 kg per ha were applied during soil preparation in the two winter seasons. Seeds of the short pea variety Master B were inoculated with *Rhizobium leguminosarum* and gum arabic was used as a sticking agent. Wheat grains (variety Gemmiza 10) were sown on 15th and 17th November at 2012 and 2013 seasons, respectively. Pea green pods were harvested on 16th and 15th December and 30th and 29th December at 2012 and 2013 seasons, respectively, and 15th and 16th January at 2013 and 2014 seasons, respectively. Wheat grains were harvested on 18th and 22nd May at 2013 and 2014 seasons, respectively. Plant density of wheat or pea per unit area did not differ between intercropping and sole crops. The experiment included three pea sowing dates (1st October, 15th October and 1st November) where wheat was grown on 15th November with application of four mineral N fertilizer (ammonium nitrate '33.5% N unit') doses (25, 50, 75 and 100 % of mineral N recommended) to wheat under intercropping and sole cultures. In terms of N, it corresponded to 44.6, 89.2, 133.8 and 178.5 kg N/ha. The treatments of intercropping pea with wheat were:

- Pea seeds were sown on 1st October in both sides of ridge (120 cm width), meanwhile six rows of wheat was grown in middle of the ridge at 15 cm between rows.
- Pea seeds were sown on 15th October in both sides of ridge (120 cm width), meanwhile six rows of wheat was grown in middle of the ridge at 15 cm between rows.
- Pea seeds were sown on 1st November in both sides of ridge (120 cm width), meanwhile six rows of wheat was grown in middle of the ridge at 15 cm between rows.

In addition to sole crops:

- Sole wheat: pure stand of wheat ridge (60 cm width) by growing three rows spaced at 15 cm on 15th November.
- Sole pea: pure stand of pea ridge (60 cm width) by growing one row in one side of the ridge on 1st October. Pea was thinned to two plants per hill at 10 cm between hills under intercropping and sole cultures. This pattern was used only for competitive relationships.

A split plot design replicated thrice was used. Treatments of pea sowing dates randomly assigned to the main plots and mineral N fertilizer doses were allocated in sub-plots. The area of plot was 14.4 m^2, it consisted of six ridges, and each ridge was 4.0 m in length and 0.6 m in width. Table (2) shows total count of rhizobia in rhizosphere of wheat roots in the first row under intercropping and sole cultures.

Table 2. *Total count of rhizobia in rhizosphere of wheat roots in the first row under intercropping and sole cultures.*

Pea sowing dates	Total count of rhizobia (cfu)			
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha
Intercropping pea with wheat				
1st October	$1.8x10^3$	$2.3x10^5$	$5.1x10^5$	$4.3x10^5$
15th October	$1.5x10^3$	$2.2x10^5$	$4.7x10^5$	$4.1x10^5$
1st November	$1.5x10^3$	$2.1x10^5$	$4.3x10^5$	$3.9x10^5$
Sole wheat	$1.1x10^3$	$1.5x10^3$	$1.5x10^3$	$1.5x10^3$

2.1. The Studied Traits

2.1.1. At 140 Days from Wheat Sowing

At 140 days from wheat sowing, the following traits measured on five wheat plants from the inner rows that included the first, the second and the third rows of both sides of the pea ridge: Flag blade leaf area (cm^2, determined as length of the blade x maximum width of leaf x 0.80 according to [15], fresh flag leaf weight (g), flag blade leaf N content (mg/g dry matter of the leaf) and chlorophyll content (mg/dm^2) and dry weight of whole plant (g). Also, total count of rhizobia in rhizosphere of wheat roots (colony forming unit 'cfu') in the first row only was performed in General Organization for Agricultural Equalization Fund, Agricultural Research Center, Giza, Egypt and Regional Center for Food & Feed, Agricultural Research Center, Giza, Egypt. The culture medium was yeast extract mannitol agar, counting method was done by dilution plate count and incubation condition was $30^{O}C/2 - 3$ days. Methods of microbial analysis were described by reference [16].

2.1.2. Yield and Its Attributes

At harvest, the following traits were measured on ten plants from each plot: Plant height (cm), number of grains/spike, grains weight/spike (g) and 1000 – grain weight (g). Wheat grain and pea seed yields/ha (ton) were recorded on the basis of experimental plot area by harvesting all plants of each plot.

2.1.3. Nitrogen Use Efficiency (NUE)

The N use efficiency of mineral N fertilization was calculated by this equation [17]:

NUE = (Grain yield$_F$ – Grain yield$_C$) / Fertilizer N applied kg/kg, where F-fertilized crop and C-unfertilized control.

2.1.4. Farmer's Benefit

Farmer's benefit (US$) was calculated as a difference between total net returns from intercropping and sole crops. Wheat grains and pea green pods prices presented by [13] were used. Net returns were calculated by subtraction the sum of fixed cost of wheat plus variable costs of both crops according to pea sowing dates and Mineral N fertilizer doses.

2.2. Statistical Analysis

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package [18]. Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% [19].

3. Results and Discussion

3.1. At 140 Days from Wheat Sowing

3.1.1. First Row of Wheat

(i). Pea Sowing Dates

Flag leaf characteristics (fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content and chlorophyll content) and dry weight of whole plant that grown at 15 cm from pea row were affected significantly by pea sowing dates at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 3). Generally, the first row of intercropped wheat with the early sowing date of pea had higher values *($P \leq 0.05$)* of fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content, chlorophyll content and dry weight of whole plant than those intercropped with pea on 1st November. In other words, intercropping wheat with pea that sown on 1st October recorded significant increase in fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content, chlorophyll content and dry weight of whole plant by 6.96, 15.38, 4.59, 4.07 and 10.58 than those intercropped with pea that sown on 1st November. These results may be attributed to the early sowing date of pea promoted rhizobia growth in rhizosphere of wheat roots more than those intercropped with pea that sown on 15th October or 1st November (Table 2). Obviously, the early sowing date of pea could be achieved better shoot and root growth of pea plant before severe inter-competition between the intercrops for basic growth resources compared the other two sowing dates of pea.

Table 3. *Effect of pea sowing dates, mineral N fertilizer and their interaction on wheat flag leaf characteristics and dry weight of whole plant in the first row, combined data across 2012/2013 and 2013/2014 seasons.*

Traits	Wheat flag leaf characteristics														
	Flag leaf blade area (cm^2)					Fresh weight of flag leaf blade (g)					Flag leaf blade N content (mg/g)				
	44.6 kg N/ha	89.2 kg N/ha	133.8 Kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat															
1st October	22.17	30.41	42.27	42.18	34.25	0.55	0.70	0.88	0.88	0.75	3.88	4.48	4.99	4.88	4.55
15th October	21.36	28.88	40.34	41.83	33.10	0.47	0.60	0.83	0.89	0.69	3.75	4.29	4.82	4.92	4.44
1st November	19.01	27.11	39.96	42.01	32.02	0.41	0.52	0.82	0.88	0.65	3.60	4.17	4.72	4.91	4.35
Average	20.84	28.80	40.85	42.00	33.12	0.47	0.60	0.84	0.88	0.69	3.74	4.31	4.84	4.90	4.44
L.S.D. 0.05 Pea sowing dates					2.14					0.09					0.18
L.S.D. 0.05 Mineral N fertilizer					1.33					0.06					0.13
L.S.D. 0.05 Interaction					3.12					0.11					0.22
Sole wheat	14.76	19.92	32.19	42.02	27.22	0.30	0.44	0.69	0.87	0.57	3.39	3.79	4.21	4.84	4.05

Table 3. *Continued.*

Traits	Wheat flag leaf characteristics Chlorophyll content (mg/dm^2)					Dry weight of whole plant (g)				
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat										
1st October	4.35	4.60	4.72	4.73	4.60	117.1	137.2	173.3	174.7	150.5
15th October	4.22	4.47	4.62	4.67	4.49	109.7	129.9	162.2	171.8	143.4
1st November	4.14	4.33	4.55	4.68	4.42	101.2	120.0	153.3	170.2	136.1
Average	4.23	4.46	4.63	4.69	4.50	109.3	129.0	162.9	172.2	143.3
L.S.D. 0.05 Pea sowing dates					0.15					14.09
L.S.D. 0.05 Mineral N fertilizer					0.11					9.83
L.S.D. 0.05 Interaction					0.18					16.37
Sole wheat	3.69	3.80	4.31	4.77	4.14	84.3	111.9	139.2	169.9	126.3

It is known that pea was characterized by a strong taproot which in its early development is profusely branched in the first 6 inches of soil [20]. Consequently, the early sowing date of pea seems to be played a positive role in inter-specific competition between pea and wheat for basic growth resources because legumes can rely on atmospheric N, they are less likely to compete for N with the cereal [21].

Accordingly, BNF process of pea (the legume component) could be contributed mainly to fulfill the N requirement of wheat (the cereal component) that grown at 15 cm from pea row by enhancing the rhizobia growth in rhizosphere of wheat roots during wheat growth and development (Table 2). When the legume plant dies, the fixed N was released; making it available to other plants and this helps to fertilize the soil [22]. So, it may be possible that soil N availability increased as result of a mix of living rhizobia and dead pea roots near the experimental soil surface after pea harvest, where the populations of rhizobia were considered as a biological pool influencing soil N dynamics. Such effect was expected because of leguminous plants could benefit the intercrop cereals in the same season through nodule decomposition [23], especially growth and development stages of wheat plant overlapped with pea flowering stage. It is well known that the symbiotic N_2 fixation activity of peas is at its maximum at the beginning of pea flowering [24].

Moreover, higher fresh weight/unit leaf area indicated larger total volume and area of multiple layers of mesophyll cells with ample N, therefore, large number of mesophyll cell utilized photosynthates in structural tissue [25]. Thus, the increase in flag leaf characteristics of intercropped wheat with pea seems to be closely related with the earliness of pea sowing date. Therefore, strong relationship between leaf N concentration and single leaf photosynthetic rates occurred which appeared to be associated with large fractions of leaf N composed in photosynthetic enzymes [26]. Accordingly, the delay in sowing date of pea from 1st October to 15th October or 1st November recorded progress of flag leaf senescence which reduced the efficiency of photosynthetic process of wheat plant. These results confirmed those obtained by reference [27], who observed that the intercropping systems influenced significantly flag leaf area and chlorophyll content.

(ii). Mineral N Fertilizer

Flag leaf characteristics (fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content and chlorophyll content) and dry weight of whole plant that grown at 15 cm from pea row were affected *($P \leq 0.05$)* strongly by mineral N fertilizer doses at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 3). Wheat plants that received the recommended mineral N fertilizer dose (178.5 kg N/ha) had the highest values of flag leaf characteristics and dry weight of whole plant compared to those received the other mineral N fertilizer doses. These results reveal that there was growth advantage of intercropped wheat with pea when wheat plants received 178.5 kg N/ha because growth resources such as water and nutrients were more completely absorbed and converted to crop biomass during growth and development stages than those received the others. Accordingly, the rate of photosynthesis which reflected on dry weight of whole plant could be maintained high during grain filling in later periods of senescence as a consequence of increase in N content of flag leaf blade. Nitrate reductase might played an important role in maintaining the balance between C and N [28]. Consequently, high carbohydrate assimilation could increase nitrate uptake and nitrate reductase activity when the plant was grown on nitrate [29]. It was known those nitrate reductase and glutamine synthetase were the key enzymes of N metabolism and involved in carbohydrate metabolism [30]. Conversely, it was observed that decreasing mineral N fertilizer from 178.5 to 44.6 kg N/ha could be decreased cell number of flag leaf that had a negative effect on flag leaf length and expansion, where N supply increased flag leaf area by increasing cell number [25].

(iii). Response of Pea Sowing Dates to Mineral N Fertilizer

Flag leaf characteristics (fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content and chlorophyll content) and dry weight of whole plant that grown at 15 cm from pea row were affected strongly by the interaction between pea sowing dates and mineral N fertilizer doses at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 3). The lowest flag leaf characteristics and dry weight of whole plant were obtained by the late sowing date of pea (1st November) with wheat that received 25 % of the recommended N fertilizer dose (44.6 kg N/ha), meanwhile, the highest flag leaf characteristics and dry weight of whole plant were obtained by the early date of pea sowing (1st October) with wheat that received 100 or 75 % of the recommended mineral N fertilizer dose (178.5 or 133.8 kg

N/ha, respectively). However, there was disadvantage of intercropping pea with wheat when wheat plants received 178.5 kg N/ha because of nitrate could be inhibited nitrogenase activity in the legume plant nodules (31). It is known that legumes have two sources of N nutrition – symbiotic N fixation of atmospheric molecular N in symbiosis with *Rhizobium* or *Bradyrhizobium* sp., and assimilation of soil N (mainly in the form of nitrates), using the enzyme nitrate reductase (32). Thus, the bacteria that actually fixed the N become lazy and N fixing declines (33). Accordingly, the efficiency of BNF process was not enhanced by the integration between the early sowing date of pea and the recommended mineral N fertilizer dose.

Therefore, the interaction between the early sowing date of pea and 75 % of the recommended mineral N fertilizer dose could be resulted in a deeper root system that make a larger volume of soil available for root extraction of water and nutrients [34] compared to the other treatments. So, it may be possible that pea sowing date on 1st October interacted with 133.8 kg N/ha to form a positive mechanism that generated stress for wheat's utilization of the available soil N compared to the other treatments, especially the morphological and physiological differences between non-legumes and legumes benefit their mutual association [35]. Although 75 % of the recommended mineral N fertilizer dose is not able to meet wheat N demand partially (especially it is expected that soil mineral N content was decreased rapidly as a result of wheat absorption), however, symbiotic N_2 fixation could be recovered, indicating that nitrate availability was not permanently detrimental to nodule activity [36]. Additionally, leaf blades had an important role in the supply of reduced N at early and late reproductive stage of uniculm wheat [25]. It seems that this ecological situation facilitated N uptake to different parts of wheat plant that grown at 15 cm from pea row during wheat growth and development, which activated the contents of N and chlorophyll in flag leaf characteristics and finally increased dry weight of whole plant. Accordingly, these results reveal that there was growth advantage of intercropped wheat with pea when wheat plants received 133.8 kg N/ha because growth resources such as water and nutrients were more completely absorbed and converted to crop biomass by enhancing efficiency of BNF process during wheat growth and development stages than those received the recommended mineral N fertilizer dose.

On the other hand, the dose of mineral N fertilizer 44.6 or 89.2 kg N/ha was not enough to interact positively with different sowing dates of pea which reflected negatively on all the studied traits of wheat. Obviously, the negative interactions between all the studied sowing dates of pea and 25 or 50% of the recommended mineral N fertilizer dose could be decreased photosynthetic and transpiration rates [37] of wheat flag leaf characteristics that reflected on dry weight of whole plant. These data reveal that there was significant effect *($P \leq 0.05$)* of the interaction between pea sowing dates and mineral N fertilizer doses on flag leaf characteristics and dry weight of whole plant.

3.1.2. Second Row of Wheat

(i). Pea Sowing Dates

Flag leaf characteristics and dry weight of whole plant that grown at 30 cm from pea row were affected significantly by pea sowing dates at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 4). Intercropped wheat with pea that sown on 1st October had higher values *($P \leq 0.05$)* of fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content, chlorophyll content and dry weight of whole plant compared to those intercropped with pea that sown on 1st November. As a result of intercropping, intercropped wheat with pea on 1st October had an increase in fresh weight of flag leaf blade, flag leaf blade area, flag leaf blade N content, chlorophyll content and dry weight of whole plant by 6.42, 15.62, 4.55, 4.20 and 7.92 % than those intercropped with pea that sown on 1st November. These data could be attributed to the early sowing date of pea had a prolonged vegetative growth of pea taproot for profusely branched to reach and activate the rhizobia growth in the rhizosphere of wheat roots that grown at 30 cm from the pea row, which reflected on flag leaf characteristics and dry weight of whole plant at 140 days from wheat sowing. It is important to mention that the early sowing date of pea furnished suitable environmental conditions about 45 days before growing wheat which allowed better growth and development of pea root to exceed a considerable distance and reach the second row of wheat compared to the other sowing dates. So, it is expected that many important aspects of plant–soil interactions such as plant nutrient [38] and root colonization by rhizosphere microorganisms [39] were mediated by rhizosphere processes. In this concern, reference [40] demonstrated that there was a tendency towards faster depth-wise root growth rate in intercropped pea roots compared to sole pea roots.

Therefore, it is likely that a network of nearly horizontal roots and their laterals of pea induced wheat roots to grow more horizontally and vertically to benefit from available soil nutrients as response of BNF process. Root system morphology and fine root distribution are believed to be key factors in determining the magnitude of below-ground inter-specific competition in intercropping systems [41].

These results reveal that the early sowing date of pea played a major role in dry matter accumulation of wheat plant where [42] showed that remobilization of N from leaves to the developing grain has been closely linked to leaf senescence. Also, reference [10] demonstrated that intercropping pea with wheat increased the proportion of N derived from symbiotic N_2 fixation and soil N accumulation. These results were in parallel with those obtained by reference [43], who showed that the surface soil at a depth of 2 to 8 inches was well filled with a network of nearly horizontal roots and their laterals to a distance of 18 inches on all sides of the plant.

Table 4. *Effect of pea sowing dates, mineral N fertilizer and their interaction on wheat flag leaf characteristics and dry weight of whole plant in the second row, combined data across 2012/2013 and 2013/2014 seasons.*

Traits	Wheat flag leaf characteristics														
	Flag leaf blade area (cm^2)					Fresh weight of flag leaf blade (g)					Flag leaf blade N content (mg/g)				
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat															
1st October	20.24	28.89	41.74	41.73	33.15	0.53	0.69	0.86	0.88	0.74	3.72	4.27	4.77	4.71	4.36
15th October	19.55	26.87	40.01	41.96	32.09	0.46	0.59	0.83	0.88	0.69	3.59	4.09	4.64	4.62	4.23
1st November	18.63	25.02	38.83	42.14	31.15	0.39	0.51	0.81	0.87	0.64	3.48	3.93	4.55	4.73	4.17
Average	19.47	26.92	40.19	41.94	32.13	0.46	0.59	0.83	0.87	0.68	3.59	4.09	4.65	4.68	4.25
L.S.D. 0.05 Pea sowing dates					1.98					0.10					0.16
L.S.D. 0.05 Mineral N fertilizer					1.79					0.06					0.11
L.S.D. 0.05 Interaction					2.12					0.12					0.18
Sole wheat	14.82	19.81	32.33	41.86	27.20	0.31	0.44	0.70	0.87	0.58	3.31	3.79	4.28	4.79	4.04

Table 4. *Continued.*

Traits	Wheat flag leaf characteristics					Dry weight of whole plant (g)				
	Chlorophyll content (mg/dm^2)									
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat										
1st October	4.12	4.42	4.66	4.66	4.46	112.3	143.6	183.9	181.3	155.2
15th October	4.00	4.26	4.53	4.69	4.37	103.1	133.8	176.1	179.5	148.1
1st November	3.89	4.10	4.43	4.72	4.28	96.6	126.1	169.7	182.9	143.8
Average	4.00	4.26	4.54	4.69	4.37	104.0	134.5	176.5	181.2	149.0
L.S.D. 0.05 Pea sowing dates					0.17					10.77
L.S.D. 0.05 Mineral N fertilizer					0.15					6.57
L.S.D. 0.05 Interaction					0.19					13.89
Sole wheat	3.62	3.71	4.27	4.70	4.07	81.6	108.3	141.7	179.8	127.8

(ii). Mineral N Fertilizer

Flag leaf characteristics and dry weight of whole plant that grown at 30 cm from pea row were affected *($P \leq 0.05$)* strongly by mineral N fertilizer doses at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 4). Wheat plants that received the recommended mineral N fertilizer dose (178.5 kg N/ha) had the highest values of flag leaf characteristics and dry weight of whole plant compared to those received the other mineral N fertilizer doses where flag leaf area could be an indicator of grain yield in wheat [44]. These results reveal that the recommended mineral N fertilizer dose could be enhanced nitrate reductase activity that reflected on flag leaf photosynthetic rates Therefore, high nitrate reductase activity contributed in N assimilation, delayed leaf senescence; sustain leaf photosynthesis, improved the efficiency of redistribution, of carbon and N assimilated prior to ear emergence, during grain formation as suggested previously [45]. On the other hand, decreasing mineral N fertilizer dose from 178.5 to 44.6 kg N/ha could be decreased soil N availability that was not able to satisfy the requirement of wheat growth and development. Obviously, N concentration of plants varies with soil N status [46].

(iii). Response of Pea Sowing Dates to Mineral N Fertilizer

Flag leaf characteristics and dry weight of whole plant that grown at 30 cm from pea row were influenced strongly by the interaction between pea sowing dates and mineral N fertilizer doses at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 4). The late sowing date of pea (1st November) interacted with 25 % of the recommended mineral N fertilizer dose (44.6 kg N/ha) to achieve the lowest flag leaf characteristics and dry weight of whole plant, meanwhile, pea sowing date on 1st October interacted with 178.5 or 133.8 kg N/ha to gave the highest flag leaf characteristics and dry weight of whole plant. It is noticed that mineral N fertilizer dose 133.8 kg N/ha induced N stress for wheat plant than the 178.5 kg N/ha. The interaction between the early sowing date of pea and 75 % of the recommended mineral N fertilizer dose formed a good environmental situation that could be stimulated a deeper growing wheat root system and a faster horizontal root development by both species indicating a potential improvement in the search of natural N sources. Significant increases in flag leaf characteristics and dry weight of whole plant could be attributed to the beneficial interaction effect of 133.8 kg N/ha and N released from symbiotic N_2 fixation through the early sowing date of pea. Exploitation of biological N was dependent on various factors like environment, nutritional status of soil and cropping strategies [47]. Clearly, pea sowing date on 1st October could be interacted positively with wheat that received 133.8 kg N/ha to benefit from the symbiotic N_2 fixation. The populations of microorganisms that make up the biological pool were the driving forces in soil nutrient dynamics [48]. These results are in agreement with those obtained by reference [49], who showed that faster root growth in barley gave access to more soil N than pea during the vegetative phase. Also, cereals were known to be more competitive for soil inorganic N than legumes at the beginning of crop growth [36].

On the other hand, mineral N fertilizer dose 89.2 or 44.6 kg N/ha interacted negatively with all the studied dates of pea sowing for the studied traits of wheat. Obviously, there was not a positive response of 25 or 50 % of the recommended mineral N fertilizer dose to all the studied sowing dates of pea for the studied traits of wheat where the photosynthetic rate/unit area of leaf depends on the development and maintenance of the photosynthetic system [50]. These data reveal that there was significant effect *($P \leq 0.05$)* of the interaction between pea sowing dates and mineral N fertilizer on flag leaf characteristics and dry weight of whole plant.

3.1.3. Third Row of Wheat

(i). Pea Sowing Dates

Flag leaf characteristics and dry weight of whole plant that grown at 45 cm from pea row were not affected significantly *($P > 0.05$)* by pea sowing dates at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 5). It is expected that microbial soil activity in the rhizosphere of intercropped wheat roots with pea that grown in the third row had the same biological interaction in the rhizosphere of sole wheat roots (Table 2), especially in the rhizosphere, plant–microbe interactions play important roles in a number of vital ecosystem processes such as nutrient cycling [51].

Table 5. *Effect of pea sowing dates, mineral N fertilizer and their interaction on wheat flag leaf characteristics and dry weight of whole plant in the third row, combined data across 2012/2013 and 2013/2014 seasons.*

Traits	Flag leaf characteristics														
	Flag leaf blade area (cm^2)					Fresh weight of flag leaf blade (g)					Flag leaf blade N content (mg/g)				
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat															
1st October	14.77	19.71	32.19	41.87	27.13	0.30	0.40	0.70	0.85	0.56	3.37	3.92	4.29	4.69	4.06
15th October	14.72	19.63	32.07	42.10	27.13	0.30	0.42	0.68	0.87	0.56	3.34	3.87	4.16	4.70	4.01
1st November	14.62	19.46	31.75	42.14	26.99	0.28	0.41	0.70	0.86	0.56	3.30	3.80	4.23	4.61	3.98
Average	14.70	19.60	32.00	42.03	27.08	0.29	0.41	0.69	0.86	0.56	3.33	3.86	4.22	4.66	4.01
L.S.D. 0.05 Pea sowing dates					N.S.					N.S.					N.S.
L.S.D. 0.05 Mineral N fertilizer					12.12					0.27					0.48
L.S.D. 0.05 Interaction					N.S.					N.S.					N.S.
Sole wheat	14.66	19.62	32.01	41.93	27.05	0.29	0.41	0.69	0.86	0.56	3.38	3.89	4.26	4.71	4.06

Table 5. *Continued.*

Traits	Flag leaf characteristics					Dry weight of whole plant (g)				
	Chlorophyll content (mg/dm^2)									
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat										
1st October	3.69	3.77	4.38	4.72	4.14	81.8	109.9	141.2	172.4	126.3
15th October	3.71	3.89	4.45	4.79	4.21	84.0	113.7	139.9	169.2	126.7
1st November	3.62	3.82	4.41	4.68	4.13	82.3	111.3	144.3	170.1	127.0
Average	3.67	3.82	4.41	4.73	4.15	82.7	111.6	141.8	170.5	126.6
L.S.D. 0.05 Pea sowing dates					N.S.					N.S.
L.S.D. 0.05 Mineral N fertilizer					0.39					30.28
L.S.D. 0.05 Interaction					N.S.					N.S.
Sole wheat	3.62	3.79	4.38	4.76	4.13	79.1	110.1	142.9	168.7	125.2

Consequently, it is expected that there was a greater intra-competition between wheat plants that grown on the second and the third rows for available soil N when the third row of wheat was far to pea row by 45 cm which might have restricted root growth and development of intercropped wheat. These results indicate that the network of horizontal pea roots and their laterals under experimental soil surface did not reach the third row of wheat among all the treatments of pea sowing dates which reflected on flag leaf characteristics and dry weight of whole plant.

(ii). Mineral N Fertilizer

Flag leaf characteristics and dry weight of whole plant that grown at 45 cm from pea row were affected *($P \leq 0.05$)* strongly by mineral N fertilizer doses at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 5). Wheat plants that received the recommended mineral N fertilizer dose (178.5 kg N/ha) had the highest values of flag leaf characteristics and dry weight of whole plant compared to those received the other mineral N fertilizer doses, especially high percentage of N contributed to maintaining photosynthetic integrity [25]. These data may be attributed to 100 % of the recommended mineral N fertilizer gave the total N requirement of wheat plants for their growth and development.

(iii). Response of Pea Sowing Dates to Mineral N Fertilizer

Flag leaf characteristics and dry weight of whole plant that grown at 45 cm from pea row were not affected by the interaction between pea sowing dates and mineral N fertilizer doses at 140 days from wheat sowing in the combined data across 2012/2013 and 2013/2014 seasons (Table 5). The third row of wheat that received 133.8 kg N/ha did not give the total N requirement of wheat plants for their growth and development. These results could be due to microbial soil activity in the rhizosphere of intercropped wheat roots with pea that grown in the third row was largely similar to that in the rhizosphere of sole wheat roots (Table 2). Accordingly, the third row of wheat that received all the studied mineral N fertilizer doses did not interact with all the studied pea sowing dates for all the studied wheat traits. These data show that there was insignificant effect *($P > 0.05$)* of pea sowing dates x mineral N fertilizer doses on flag leaf characteristics and dry weight of whole plant.

3.2. Yield and Its Attributes

3.2.1. Pea Sowing Dates

Number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha were affected significantly by pea sowing dates in the combined data across 2012/2013 and 2013/2014 seasons (Table 6). Intercropped wheat plants with pea that sown on 1st October had higher values *($P \leq 0.05$)* of number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha than those intercropped with pea that sown on 1st November. The highest grain yield of intercropped wheat related to the first pea sowing date recorded average of 5.71 ton/ha and the lowest grain yield of intercropped wheat related to the third pea sowing date had average of 5.51 ton/ha (Table 6). It seemed that the early sowing date of pea could be increased number and ability of florets to set grain which caused higher number of grains/spike, grains weight/spike and 1000 – grain weight than those intercropped with pea that sown on 1st November.

Table 6. *Effect of pea sowing dates, mineral N fertilizer and their interaction on wheat grain yield and its attributes, combined data across 2012/2013 and 2013/2014 seasons.*

Traits	Number of grains/spike					Grains weight/spike (g)				
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat										
1st October	28.53	42.63	62.01	62.30	48.86	1.71	2.09	2.68	2.78	2.31
15th October	26.35	41.43	61.85	62.24	47.96	1.59	1.82	2.66	2.74	2.20
1st November	24.54	39.69	61.72	62.19	47.03	1.40	1.68	2.60	2.68	2.09
Average	26.47	41.25	61.86	62.24	47.95	1.56	1.86	2.64	2.73	2.19
L.S.D. 0.05 Pea sowing dates					1.65					0.12
L.S.D. 0.05 Mineral N fertilizer					0.31					0.08
L.S.D. 0.05 Interaction					2.22					0.14
Sole wheat	21.72	34.93	56.43	62.02	43.77	1.25	1.51	2.41	2.70	1.96

Table 6. *Continued.*

Traits	1000 – grain weight (g)					Grain yield/ha (ton)				
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat										
1st October	36.71	40.25	48.74	48.76	43.61	3.89	5.10	6.87	6.98	5.71
15th October	35.46	39.81	48.68	48.71	43.16	3.67	4.90	6.82	6.94	5.58
1st November	34.22	38.52	48.63	48.73	42.52	3.49	4.82	6.75	6.99	5.51
Average	35.46	39.52	48.68	48.73	43.09	3.68	4.94	6.81	6.97	5.60
L.S.D. 0.05 Pea sowing dates					0.11					0.19
L.S.D. 0.05 Mineral N fertilizer					0.03					0.12
L.S.D. 0.05 Interaction					0.16					0.22
Sole wheat	32.43	37.18	45.39	48.74	40.93	3.38	4.23	6.22	7.02	5.21

These results could be due to pea sowing date on 1st October then growing wheat in the same ridge after 45 days from pea sowing formed suitable growth resources which reflected on delaying flag leaf senescence during wheat growth and development compared to the two other sowing dates of pea. The early date of pea sowing enhanced the efficiency of BNF process and improved flag leaf characteristics which maintaining photosynthetic integrity during wheat growth and development (Table 2) and more photosynthates in developing grains/spike (Table 6). Also, it is important to mention that the harvest date of pea played a major role to minimize the adverse effects of intercropping conditions on wheat productivity. Prior to grain filling, N is required for canopy establishment and also for root growth and development of wheat. Compared to other leaves, the flag leaf contributes the most photosynthetic assimilated in wheat which was important in grain yield [52]. Grain yield was dependent on the rate and duration of grain filling [53]. Also, physiological studies of wheat had indicated that flag leaf contribution towards grain weight accounts for 41 – 43 % of dry matter in the kernel at maturity and its major photosynthetic sites during the grain filling stage [54]. Moreover, leaf is an important N source for the grain after flowering [55]. Furthermore, grain weight/spike was very important yield components, which directly influenced to yield and depended on grain number and grain chemical composition [56].

With respect to green pod yield/ha of pea, it was affected significantly by pea sowing dates in the combined data across 2012/2013 and 2013/2014 seasons (Figure 1). Intercropping pea with wheat decreased significantly green pod yield/ha compared to sole pea. In this concern, reference [57] had similar results, who indicated that sole pea yielded better than intercrops.

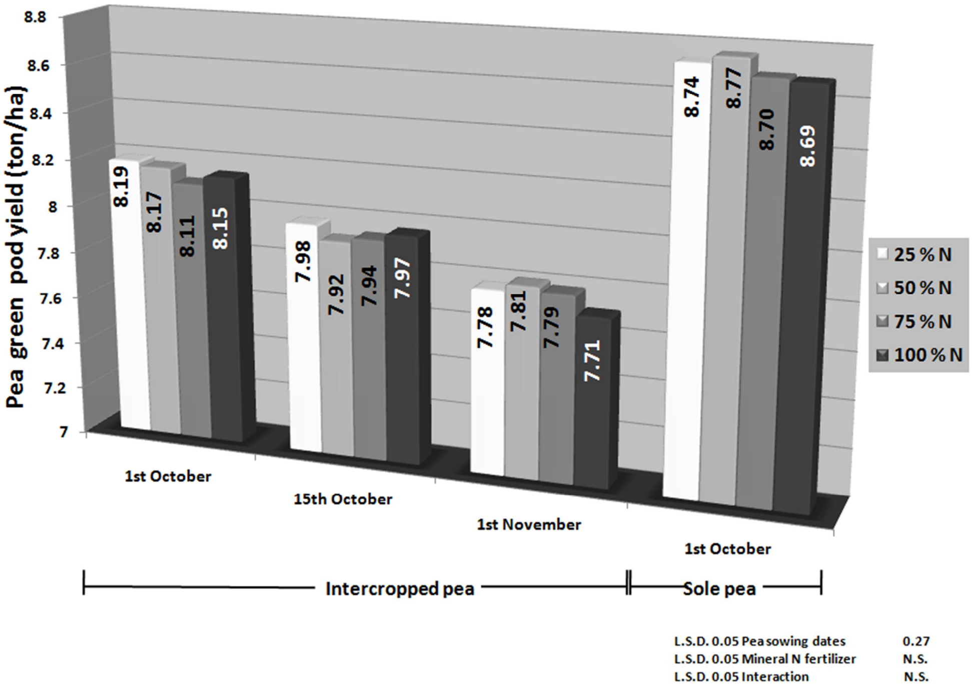

Figure 1. *Pea green pod yield as affected by pea sowing dates, mineral N fertilizer and their interaction, combined data across 2012/2103 and 2013/2014 seasons.*

These results reveal that there had been yield advantage because the growth resources such as light, water, and nutrients were completely absorbed and converted to crop biomass by the intercrop over time and space as a result of differences in competitive ability for growth resources between the component crops [58], especially yield increase would effectively tackled on the basis of the performance of yield components and other closely associated characters [59]. Also, reference [10] demonstrated that growing pea with wheat increased grain dry matter. Moreover, grains/spike had positive direct effect on grain yield [60].

3.2.2. Mineral N Fertilizer

Number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha were affected significantly by mineral N fertilizer doses in the combined data across 2012/2013 and 2013/2014 seasons, whereas, pea green pod yield/ha was not affected (Table 6 and Figure 1). Mineral N fertilizer dose 44.6 or 89.2 kg N/ha had negative effects on all the studied wheat traits at harvest as a result of N deficiency which could be decreased spikelet number and delayed time of double row and terminal spikelet [61]. Conversely, wheat plants that received 178.5 kg N/ha had the highest values of number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha. This could be justified with logic that N availability satisfied wheat requirement for growth and development, which enabled the plant to produce more number of grains/spike. Obviously, the number of grains/spike was increased by increasing mineral N fertilizer dose for wheat plant [62]. These data attributed to the adequate mineral N dose (178.5 kg N/ha), which might facilitate the tillering ability of the plants, resulting in greater spike population [63]. It is known that assimilates availability from flag leaf developed under high N supply determined the number of fertile florets at anthesis and in turn final grain number and that would be key trait to improve wheat yield without changing the anthesis date [25].

3.2.3. Response of Pea Sowing Dates to Mineral N Fertilizer

Number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha were affected strongly by pea sowing dates x mineral N fertilizer doses in the combined data across 2012/2013 and 2013/2014 seasons, whereas, pea green pod yield/ha was not affected (Table 6 and Figure 1). The lowest number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha were obtained by pea sowing date on 1st November with wheat that received 44.6 kg N/ha, meanwhile, the highest number of grains/spike, grains weight/spike, 1000 – grain weight and grain yield/ha were obtained by pea sowing date on 1st October with wheat that received 133.8 kg N/ha. These data could be attributed to pea sowing date on 1st October interacted positively with wheat that received 133.8 kg N/ha to improve flag leaf characteristics by absorbed more soil N availability through enhancing the efficiency of BNF process (Table 2) during wheat growth and development compared to the other treatments, especially nodulation and N fixation by legumes is adversely affected by higher doses of fertilizer N [64]. These data show that there was effect *($P \leq 0.05$)* of pea sowing dates x mineral N fertilizer doses on flag leaf characteristics and dry weight of whole plant. Similar results were observed by reference [10], who demonstrated that intercrops of pea and wheat had maximum productivity without the supply of N fertilizer.

3.3. Nitrogen Use Efficiency (NUE)

3.3.1. Pea Sowing Dates

NUE values varied from 19.1 kg per kg in sole crop with the highest range of 44.6 – 178.5 kg N/ha up to 36.54 kg/kg in intercropped wheat with pea that sown on 1st November with the medium range of 44.6 – 133.8 kg N/ha. NUE was affected significantly by pea sowing dates in the combined data across 2012/2013 and 2013/2014 seasons (Figure 2). Intercropping pea with wheat increased NUE by 12.45 % compared to sole wheat. With respect to pea sowing dates, NUE was not changed among pea sowing dates. These results show that intercropping pea with wheat in the same ridge increased total count of rhizobia in rhizosphere of intercropped wheat roots that affected positively N content in tissues of intercropped wheat and increased grain yield/unit area. These results were in accordance with those obtained by reference [65], who indicated that the crop mixture contained a greater quantity of N than did the monocultures (sole crops), indicating synergism in N use for the intercrops. Also, reference [66] found that the utilization of different chemical forms of N by companion plants could provide a means of N use complementarily. They added that the presence of field pea in crop treatments reduced unit area demands for soil NO_3, thereby freeing up this resource for non-legume crop uptake.

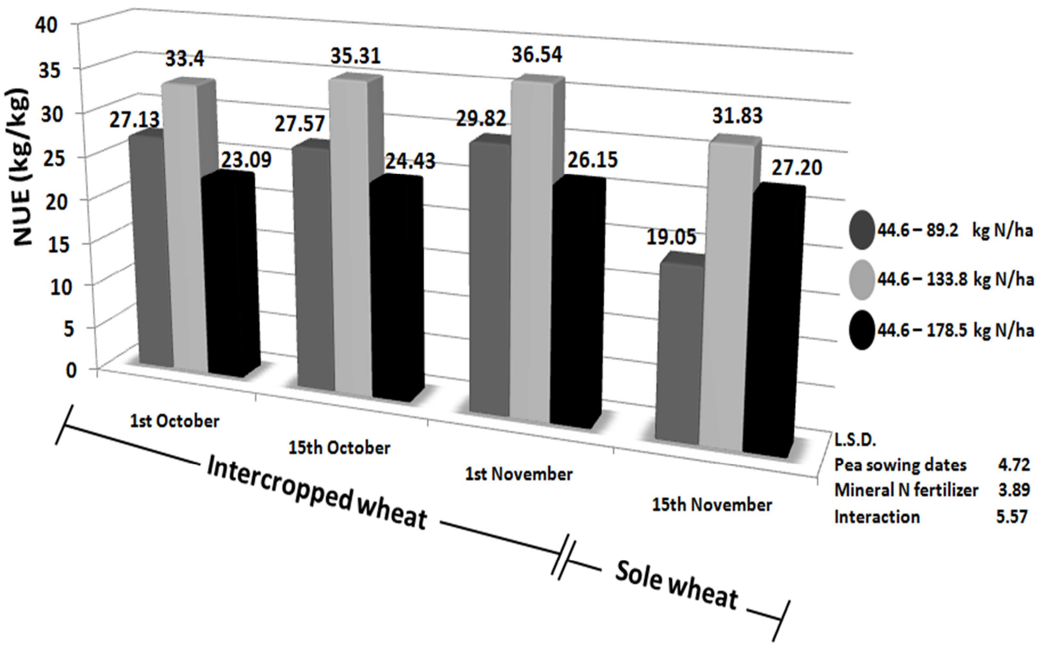

Figure 2. Nitrogen use efficiency (NUE) affected by pea sowing dates, mineral N fertilizer and their interaction, combined data across 2012/2013 and 2013/2014 seasons.

3.3.2. Mineral N Fertilizer

NUE was affected significantly by mineral N fertilizer doses in the combined data across 2012/2013 and 2013/2014 seasons (Figure 2). Wheat plants that received 133.8 kg N/ha had the highest NUE, while the lowest NUE was recorded when wheat plants received 178.5 kg N/ha. These results confirm that intercropping pea with wheat improved the utilization of N compared to sole wheat which indicating the recommended mineral N fertilizer dose had negative effect *($P \leq 0.05$)* on NUE.

3.3.3. Response of Pea Sowing Dates to Mineral N Fertilizer

NUE was affected significantly by pea sowing dates x mineral N fertilizer doses in the combined data across 2012/2013 and 2013/2014 seasons (Figure 2). The lowest NUE was obtained by sole wheat that received 178.5 kg N/ha, meanwhile, the highest NUE was obtained by intercropping pea with wheat that received 133.8 kg N/ha. These data show that each of these two factors act dependently on NUE meaning that pea sowing dates responded differently *($P \leq 0.05$)* to mineral N fertilizer doses for NUE. With regard to N, different studies have shown that the addition of organic residues may facilitate transformation of fertilizer or soil N into a slowly available N source and thus may improve N efficiency [67].

3.4. Competitive Relationships

3.4.1. Pea sowing Dates

The values of LER and LEC were estimated by using data of sole crops. LER was affected significantly by pea sowing dates in the combined data across 2012/2013 and 2013/2014 seasons (Table 7). In general, intercropping pea with wheat increased *($P \leq 0.05$)* LER compared to sole crops. It ranged from 1.03 by pea sowing date on 1st November with wheat that received 44.6 kg N/ha to 1.68 by pea sowing date on 1st October with wheat that received 178.5 kg N/ha with an average of 1.40. The advantage of the highest LER by intercropping pea with wheat over sole crops could be due to plant population density of pea and wheat that reached 100 % of sole crops.

Moreover, the early sowing date of pea caused significant increments in LER compared to the other two sowing dates of pea. These results could be attributed to root growth pattern may be changed by management parameters employed and improved growth of intercropped wheat as the result of changes in inter-specific competition between pea and wheat for basic growth resources. These results were in conformity with those obtained by reference [68], who demonstrated that all the possible combinations of intercropping treatments (wheat + pea) gave LER values greater than one. Also, reference [27] found that the intercropping systems significantly influenced LER.

LEC was a measure of interaction concerned with the strength of relationship. LEC is used for a two- crop mixture the minimum expected productivity coefficient (PC) is 25 per cent, that is, a yield advantage was obtained if LEC value was exceeded 0.25. LEC was affected significantly by the pea sowing dates in the combined data across 2012/2013 and 2013/2014 seasons (Table 7). Mean LEC of intercropping pea with wheat was exceeded 0.25 and consequently the wheat + pea intercropping had yield advantage. Generally, intercropped wheat with pea had the highest values *($P \le 0.05$)* of LEC than sole crop. Moreover, the early sowing date of pea caused significant increments in LEC compared to those intercropped with pea that sown on 15th October and 1st November. The advantage of the highest LEC by intercropping pea with wheat over sole crops could be due to plant population density of pea and wheat reached 100 % of sole crops.

Table 7. *LER and LEC as affected by pea sowing dates, mineral N fertilizer and their interaction, combined data across 2012/2013 and 2013/2014 seasons.*

Traits	LER					LEC				
	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average	44.6 kg N/ha	89.2 kg N/ha	133.8 kg N/ha	178.5 kg N/ha	Average
Intercropping pea with wheat										
1st October	1.23	1.39	1.67	1.68	1.49	0.37	0.48	0.67	0.68	0.55
15th October	1.13	1.27	1.57	1.60	1.39	0.31	0.40	0.58	0.60	0.47
1st November	1.03	1.21	1.51	1.54	1.32	0.26	0.36	0.52	0.54	0.42
Sole crop	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
L.S.D. 0.05 pea sowing dates					0.25					0.16
L.S.D. 0.05 Mineral N fertilizer					0.15					0.10
L.S.D. 0.05 Interaction					0.32					0.21

3.4.2. Mineral N Fertilizer

LER and LEC were affected significantly by mineral N fertilizer doses in the combined data across 2012/2013 and 2013/2014 seasons (Table 7). Increasing mineral N fertilizer doses up to 75 % of the recommended mineral N fertilizer dose increased *($P \le 0.05$)* LER and LEC. These results confirm that intercropping pea with wheat improved the utilization of N compared to sole wheat. These results were in the same content with those observed by reference [40], who showed that the LER values based on total N accumulation indicated that N was used 10 – 30% more efficiently in intercrops than sole crops.

3.4.3. Response of Pea Growing Dates to Mineral N Fertilizer

LER and LEC were affected significantly by pea sowing dates x mineral N fertilizer doses in the combined data across 2012/2013 and 2013/2014 seasons (Table 7). The lowest LER and LEC were obtained by pea sowing date on 1st November with wheat that received 44.6 kg N/ha, meanwhile, the highest LER and LEC were obtained by pea sowing date on 1st October with wheat that received 178.5 kg N/ha. These data show that each of these factors act dependently on LER and LEC meaning that pea sowing dates responded differently *($P \le 0.05$)* to mineral N fertilizer doses for each of LER and LEC.

3.5. Farmer's Benefit

The financial returns of intercropped wheat as compared to sole crop are shown in Table (8). Intercropping pea with wheat increased total and net returns compared to sole wheat.

Net returns from intercropped wheat varied between treatments from US$ 1764 to 2890/ha compared to sole wheat (US$ 311/ha).). Intercropping pea with wheat gave the highest financial value by pea sowing date on 1st October with wheat that received 133.8 kg N/ha. These results indicate that pea sowing date on 1st October with wheat that received 178.5 kg N/ha is more profitable to farmers than sole wheat for Egyptian farmers. These findings were parallel with those obtained by reference [68], who concluded that intercropping wheat with pea was profitable and hence this study should be popularized in the developing countries.

Prices of main products are that of 2012: $ 320.0 for ton of wheat; $ 336.0 for ton of pea; intercropping pea with wheat increased variable costs of intercropping culture from US$ 2024 – US$ 2215/ha over those of sole wheat.

4. Conclusion

Our results revealed that maximum distance between pea row and wheat row in the same ridge should not exceed 30 cm apart between the two species to use 75 % of the recommended mineral N fertilizer for wheat plants. Growing pea on 1st October in both sides of ridge (120 cm width), with growing three rows of wheat at 15 cm between rows on middle of the pea ridge after 45 days from pea sowing should be encouraged in wheat fields. Intercropping pea with wheat seemed well adapted to the Egyptian conditions and could be an alternative way to decrease N inputs of wheat by about 25 % through increasing NUE of wheat. Intercropping pea with wheat increased net income by US$ 2547/ha compared to sole wheat.

Table 8. *Financial return as affected by pea sowing dates, mineral N fertilizer and their interaction, combined data across 2012/2013 and 2013/2014 seasons.*

Traits	**Wheat**					**Pea**				
	44.6 kg N/ha	**89.2 kg N/ha**	**133.8 kg N/ha**	**178.5 kg N/ha**	**Average**	**44.6 kg N/ha**	**89.2 kg N/ha**	**133.8 kg N/ha**	**178.5 kg N/ha**	**Average**
Intercropping pea with wheat										
1st October	1244	1632	2198	2233	1826	2751	2745	2724	2738	2739
15th October	1174	1568	2182	2220	1786	2681	2661	2667	2677	2671
1st November	1116	1542	2160	2236	1763	2614	2624	2617	2590	2611
Sole wheat	1081	1353	1990	2246	1667	---	---	---	---	---
Sole pea	---	---	---	---	---	2936	2946	2923	2919	2931

Table 8. *Continued.*

Traits	**Total**					**Net**				
	44.6 kg N/ha	**89.2 kg N/ha**	**133.8 kg N/ha**	**178.5 kg N/ha**	**Average**	**44.6 kg N/ha**	**89.2 kg N/ha**	**133.8 kg N/ha**	**178.5 kg N/ha**	**Average**
Intercropping pea with wheat										
1st October	3995	4377	4922	4971	4574	2029	2362	2858	2857	2526
15th October	3855	4229	4849	4897	4441	1889	2214	2785	2783	2417
1st November	3730	4166	4777	4826	4346	1764	2151	2713	2712	2335
Sole wheat	1081	1353	1990	2246	1667	(-201)	22	609	815	311
Sole pea	2936	2946	2923	2919	2931	1626	1636	1613	1609	1621

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