Research Article

Nitrogen Split Application Timing Effect on Wheat Intercrop with Selected Species for Sustainable Production

Muhammad Salman Wazir and Mohammad Akmal

Department of Agronomy, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.

Abstract | This study was focused on N split application timing effect on wheat performance as sole or intercrop with other selected species. The study was conducted at Agronomy Research Farm, the University of Agriculture, Peshawar, during winter 2015-16. Treatments included cropping pattern viz. sole and intercrop of lines with 1:1 ratio i.e. one wheat row followed by one other crop species and 2:1 ratio i.e. two wheat rows followed by one other crops rows of Brassica (*Brassica juncea*), Fababean (*Vicia faba*) and Sunflower (*Helianthus annuus*), hereafter, referred as IC-I and IC-II. The N splits were applied of the total recommended 120 kg ha^{-1} N in splits, i.e. N splits application (NS) *viz.* NS_1 (50% sowing and 50% tillering), NS_2 (25% sowing: 50% tillering and 25% anthesis) and NS_3 (25% sowing, 25% tillering and 50% anthesis). Experimental design was a randomized complete block, replicated three times. Results showed a delay in maturity with taller plants at the split N application of NAT_2 and NS_3 as compared to the NS_1. Likewise, better traits of wheat plant and hence the yield including grain wet gluten content were reported for the treatment NS_3 as sole wheat crop, followed by the intercropped with fababean. Among the intercropping, IC-I with fababean showed better future scope of wheat crop production under the changing climate to produce higher production per unit area with sustainable soil use under cereal cropping system. Among the tested species sunflower and flax were not suitable choices as IC with wheat. The study concluded with the expected increase in rainfall of the changing climate in KP which is expected at the time of the wheat crop at anthesis, three N splits application i.e. NS_2 and NS_3 are the best options over NS_1 for wheat crop in KP. Further, to adding that it minimized lodging resistant of intercrop over sole wheat and that wheat intercrop with fababean has a potential to harvest quality grains with sustainable soil management at wheat – maize cropping system.

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***Correspondence** | Mohammad Akmal, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; **Email:** akmal@aup.edu.pk
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Introduction

Wheat (*Triticum aestivum* L.) belongs to the family Poaceae. It is an important cereal used as staple food in the Asia. Its role in terms of production and consumption is equally important for Pakistan's economy and hence, ranked 3rd for area under cultivation (MNFS & R, 2016). Wheat is grown annually for more than 25 million tons' grains production. It is expected to increase wheat demand with the growing population in future. In Khyber Pakhtunkhwa (KP) province, 62% wheat crop is grown as rainfed, which resulted in half of the national average (MNFS & R, 2016). Delay in winter rain experienced its late sowing and unexpected early summer rains adversely affect yield with lodging at physiological maturity (Hanif and Ali, 2014). Intercrop is sophisticated agro-technique, to grow two crops together. It helps to increase multiplicity in the cropping system, which results in maximum yield with efficient use of the available resources (Lithourgidis et al., 2011). Yield of a companion crop is ensured. It is some time reported higher in contrast to a sole crop (Liu et al., 2006). Intercrop is substantial for development of maintainable food production of cereal with legume (Adesogan et al., 2002). It has a significant influence on the growth and yield of any other companion crops (Ali et al., 2000; Khan et al., 2005). Wheat-soybean and wheat-maize strip intercropping has led to advantage +40% yield of wheat over the sole maize (Long et al., 2001). Wheat intercrop with brassica for rainfed cropping system is traditional practice and is found successful in Pakistan. It is not only avoiding risk of crop failure but also have found profitable in most cases over the sole wheat crop (Khan et al., 2014).

Keeping in view the current scenario of the climate change and moist windy spring season extended to early summer resulted partial to complete lodging in wheat crop. This not only adversely affects the yield but also creates hurdle in harvesting and hence increase production cost with manual harvesting of wheat crop. In addition to that, fertility of the soil is adversely affected by leaching of N during grain filling which results in lower grain protein. This creates issues for baking quality of the wheat grains. Nitrogen occupies a pivotal position in plant metabolism. Protein, which is associated with all vital process of plant, is mainly composed of N. Application of N fertilizer is very necessary for wheat production (Kichey et al., 2007). Nonetheless, timing of N application corresponds to plant development stages is becoming more important for effective utilization. Efficient use of N-fertilizer with appropriate timing is essential to overcome production cost (Ahmad et al., 2002) and to sustain grain quality. From one to two splits, the N application to soil has proved better use efficiency in crops. However, current change in climate scenarios demands detailed investigation of further split N application for better grain quality with minimizing production cost.

Objective of this study was to examine intercrop over sole crop of wheat with an assortment of three split N applications to wheat for improved grain yield and quality. We also strive for sustainable soil fertility status for following crops on field remains under cereal based cropping system and to minimize N-leaching with higher rains at grain development stage.

Materials and Methods

Location and site

Field experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar, during winter 2015-16. Experimental location was 34.01^0 N and 71.35 ^{0}E at an altitude of 359 m at Peshawar. Peshawar is the capital of KP, located at 1600 km at N of Indian Ocean and has continental climate. Weather scenarios i.e. temperature and rainfall received during the crop growth period are shown in Figure 1.

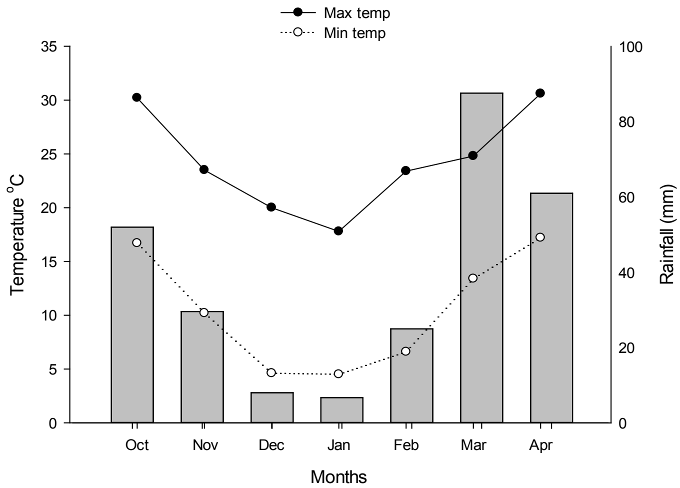

Figure 1: *Mean monthly maximum, minimum temperature (^{0}C) and rainfall (mm) of the season observed during the crop growth.*

Design and treatments

The study was conducted in a randomized complete block design (RCBD), split plots in three replications. Two factors experiment viz. (a) sole vs. intercrop and (b) nitrogen split applications (NS) were compared for wheat grain yield and quality. Experimental unit was 4.0 m x 2.0 m. For sole wheat crop 10 rows of wheat were accommodated at 0.20 m spacing. Whereas, for other crop species (i.e. Brassica, Flax, Fababean and Sunflower) 5 rows were accommodated in an experimental unit at 0.40 m spacing as per crop canopy structure requirements. For the intercropping, two strips were used (a) i.e. one row of wheat with one row of other selected species (i.e. 1:1) and (b) two rows of wheat followed by one row of other species (i.e. 2:1). Intercrops as treatment were assigned to main plots and NS to subplots. All other cultural operations were kept uniform for plots focusing on wheat as the main crop of this study. The following treatment combinations were studied.

Factor A (Crops)

1. Sole Wheat (*Triticum aestivum*) = (10 Wheat rows at 20 cm)

2. Sole Brassica (*Brassica napus.*) = (5 Brassica rows at 40 cm)
3. Sole Fababean (*Vicia faba*) = (5 Fababean rows at 40 cm)
4. Sole Flax (*Linium usitatissimum*) = (5 Flax rows at 40 cm)
5. Sole Sunflower (*Helianthus annuus*) = (5 Sunflower rows at 40 cm)
6. Wheat-Brassica intercropped-l = (4 wheat at 20 cm + 3 Brassica at 40 cm as 1:1)
7. Wheat-Fababean Intercropped-I = (4 wheat at 20 cm + 3 Fababean at 40 cm as 1:1)
8. Wheat-Flax intercropped-l = (4 wheat rows at 20 cm + 3 Flax at 40 cm as 1:1)
9. Wheat-Sunflower Intercropped-I = (4 wheat at 20 cm + 3 Sunflower at 40 cm as 1:1)
10. Wheat-Brassica intercropped-II = (6 wheat at 20 cm + 2 Brassica at 40 cm as 2:1)
11. Wheat-Fababean intercropped-II = (6 wheat at 20 cm + 2 Fababean at 40 cm as 2:1)
12. Wheat- Flax intercropped-II = (6 wheat at 20 cm + 2 Flax at 40 cm as 2:1)
13. Wheat-Sunflower intercropped-II = (6 wheat at 20 cm + 2 Sunflower at 40 cm as 2:1)

Note: Sowing of wheat and intercrop species made on November 20, 2015 but sunflower planted on February 15, 2016 in this experiment.

Factor B (N-Split application)

1. $NS_{1=}$ (50% N applied at seedbed and 50% at tillering (70 DAS).
2. $NS_{2=}$ (25% N applied at seedbed, 50% at tillering (70 DAS) and 25% at anthesis (110 DAS).
3. $NS_{3=}$ (25% N applied at seedbed, 25% at tillering (70 DAS) and 50% at anthesis (110 DAS).

Note: Nitrogen was applied as recommended (120 kg ha^{-1}) in splits as per above fractions.

Measurements and observations

Soil samplings: A composite soil sample during seedbed preparation was randomly collected using auger from different locations (15-30 cm depth). Similarly, the rest sampling was done at anthesis (123 days after sowing DAS) and harvest (170 DAS) stages of the crop from each experimental unit. Soil samples were collected in bags and air-dried in lab for 3-4 days. Clean grounded sample (0.2 g) was taken in digestion tube for soil total N, added with 1.3 g digestion mixture ($CuSO_4$ and K_2SO_4) and 3 ml of H_2SO_4 in digestion assembly, then heated with burner till the appearance of the greenish color. Mixture was filtered and added with distilled water to make volume 100 ml. A sample of 20 ml heated mixture along with 20 ml NaOH solution was taken in a wolf bottle for distillation. An indicator 5 ml (Boric acid mixed indicator) with 40 ml distillate was taken in a conical flask, titrated with 0.005 N HCL till the appearance of a pink color. The HCL consumed was noted and soil total N was derived from the Equation 1.

$$N\ (\%) = \frac{(\text{Sample-Blank}) \times \text{Normality of acid} \times \text{Volume made} \times \text{N mol.weight}}{\text{Weight of soil sample} \times \text{Volume taken}} \times 100$$

Field observations: Days to anthesis were recorded manually by counting days from sowing to anthesis when 50% anthesis was completed in an experimental unit. Similarly, days to maturity were also calculated by counting days taken from sowing to date when almost 50% plants turned yellow. Plant height (cm) was recorded by measuring 10 representative plants in an experimental unit from base to tip and averaged. Tillers m^{-2} were recorded by counting tillers at 0.5m rows at three locations. Grain spike^{-1} were counted manually to thresh grains in 10 randomly selected spikes and averaged. Spike length (cm) was measured with measuring tape on 10 randomly selected spikes and averaged. Same spikes were used for spike weight (g). Data regarding grain yield and biomass (kg ha^{-1}) were recorded on four central rows harvested, bundled and allowed to dry for about 10 days in the field. Each bundle was weighed individually to record above ground biomass. The same bundle was independently threshed at farm yard and grains were weighed for grain yield data. Harvest index (%) was derived as ratio of grains to biomass. The 1000 grain weight (g) was noted on randomly grain samples collected at harvest and counted on a seed counter. Hand wash method used for grain wet gluten (GWG) determination (%) (AACC, 2004). Samples collected for spike length were threshed, grains collected in the paper bag, ground on a mini-lab grinding mill (Cyclone Mill Twister). Ground sample (25 g) of an experimental unit was mixed with 15 ml distilled water to make dough. Dough was put in a two-ply cheese-cloth and allowed to stand for 1 h. Starch and soluble matter was removed manually by pressing dough under running water. Dough-ball was then placed in a tarred, flat-bottomed dish and weighted as moist gluten. Wheat wet gluten (%) was determined.

Data were statistically analyzed using analysis of variance technique suitable for the randomized complete block design (Steel et al., 1997). Least significant difference test (p≤0.05) was used for mean separation of treatments.

Results and Discussions

Plant morphology

Emergence (m^{-2}) and days to emergence did not differ for the treatment NS and/or sole vs. intercrop (data not shown). Days to anthesis did influence by IC and NS with higher for the NS_2 with maximum days to anthesis (Table 1). Among IC treatments, wheat sole, wheat-flax, wheat-brassica and wheat-fababean were alike. Interactions of paired treatments did not vary for days to anthesis. Days to physiological maturity did not vary for NS_2 and NS_3 but did from NS_1. Wheat-fababean IC-I, wheat-sunflower IC-I, wheat-brassica IC-II and wheat-fababean IC-II were statistically similar for days to maturity. Interaction of sole vs. IC, sole vs. IC-I, sole vs. IC-II was found significant for days to physiological maturity of wheat crop. Data on plant height of wheat were affected by NS_2 vs. NS_1 but did not differ between NS_2 and NS_3. Treatments IC were similar for wheat plant height but wheat-sunflower only. Planned mean comparisons showed significant responses of plant height in SC vs. IC-II and IC-I vs. IC-II. Tiller number per unit area did not differ by any of the treatments or their combinations for wheat (data not shown).

Yield traits

Data regarding grain number per spike did vary for the NS and IC (Table 2). Grain number per spike was higher in NS_3 than NS_2 which also did not vary from NS_1. Among the IC treatments, grain number per spike was observed the highest for wheat-fababean IC-I and IC-II, which were statistically same as observed for the sole wheat. The rest of IC decreased grain number per spike. Paired mean comparison showed significant change in grain number for sole vs. IC, sole vs. IC-I, sole vs. IC-II. Spike length (cm) of wheat was found statistically similar for NS_2 and NS_3 but lower for the NS_1. Among the IC, spike length of sole wheat crop was similar with wheat-flax IC-I, wheat-sunflower IC-I, wheat-brassica IC-II wheat-flax IC-II and wheat-sunflower IC-II. Planned mean comparison did not show any change in the spike length of wheat crop. Data regarding spike weight (g) of wheat was influenced by NS with highest for NS_2, followed by NS_3 and the lowest for NS_1 (Table 2). Intercrop wheat with any other species as IC-I and IC-II did not show any change in spike weight of wheat crop but found lower than sole wheat. Similarly, the planned mean comparisons showed a significant effect of spike weight for sole vs. IC, sole vs. IC-I, sole vs. IC-II, IC-I vs. IC-II. Data pertaining to 1000 grain weight (g) of wheat was affected by NS with higher for NS_3 than NS_2 with no change between NS_2 and NS_1. Among the intercropping, wheat-fababean IC-I and IC-II, wheat-sunflower IC-II and sole wheat reflected the same 1000 grain weight. Planned mean comparison showed significant effect on 1000 grain weight for sole vs. IC, sole vs. IC-I and sole vs. IC-II.

Table 1: *Phenological parameters of wheat crop as influenced by wheat sole vs. intercrop (IC) and N-Split application (NS) during the crop growth.*

Crops	Days to		Plant height (cm)
	Anthesis	Maturity	
Sole Wheat	123.8 a-c	160.7 d	90.1 b
Wheat + Brassica IC-I	123.3 b-d	161.0 cd	90.4 b
Wheat + Fababean IC-I	124.6 a	162.4 a	89.5 b
Wheat + Flax IC-I	123.3 b-d	160.9 cd	89.4 b
Wheat + Sunflower IC-I	123.9 a-c	161.7 a-c	91.0 b
Wheat +Brassica IC-II	123.1 cd	161.7 a-c	90.1 b
Wheat + Fababean IC-II	124.3 ab	162.1 ab	94.9 a
Wheat + Flax IC-II	123.6 b-d	161.6 b-d	93.8 b
Wheat + Sunflower IC-II	123.1 d	161.0 cd	94.5 a
N-Split Application (NS)			
NS_1	123.5 b	160.7 b	90.1 b
NS_2	124.1 a	161.6 a	91.9 a
NS_3	123.4 b	162.0 a	92.5 a
Planned mean comparisons			
Sole crop (SC) vs. Inter-crop (IC)	NS	*	NS
SC vs. IC-I	NS	*	NS
SC vs. IC-II	NS	*	*
IC-I vs. IC-II	NS	NS	***
LSD (0.05)			
Inter crop (IC)	1.1	0.9	3.1
Nitrogen Split (NS) application	0.6	0.5	1.1
IC x NAT	NS	NS	NS

Means within a category followed by different letters are different (p≤0.05) using LSD test.
**Nitrogen Split Application (NS);* NS_1*: 50% at seedbed and 50% at tillering (70 DAS) of the recommended 120 kg N ha*$^{-1}$*;* NS_2*:25% at seedbed, 50% at tillering (70 DAS) and 25% at anthesis (110 DAS);* NS_3*: 25% at seedbed, 25% at tillering (70 DAS) and 50% at anthesis (110 DAS).*

Table 2: *Yield contributing traits of wheat crop as influenced by wheat sole vs. intercrop (IC) and N-Split application (NS) during the crop growth.*

Crops	Grains spike⁻¹	Spike length (cm)	Spike weight (g)	1000 grain weight (g)
Sole Wheat	48.3 a	10.8 a-d	3.5 a	48.7 a
Wheat + Brassica IC-I	41.5 c	10.4 cd	3.2 b	46.3 e
Wheat + Fababean IC-I	46.1 ab	10.3 d	3.3 b	47.6 a-d
Wheat + Flax IC-I	43.6 bc	11.1 ab	3.3 b	46.9 c-e
Wheat + Sunflower IC-I	43.0 bc	11.4 a	3.3 b	47.0 b-e
Wheat +Brassica IC-II	42.8 bc	11.1 a-c	3.5 a	46.4 de
Wheat + Fababean IC-II	47.6 a	10.6 b-d	3.3 b	48.1 ab
Wheat + Flax IC-II	44.9 bc	10.7 a-d	3.2 b	47.0 de
Wheat + Sunflower IC-II	42.6 c	11.0 a-c	3.3 b	47.1a-c
N-Split Application (NS)				
NS_1	43.7 b	10.5 b	3.2 c	46.8 b
NS_2	43.6 b	10.9 a	3.4 a	47.0 b
NS_3	46.2 a	11.0 a	3.3 b	48.0 a
Planned mean comparisons				
Sole crop (SC) vs. Intercrop (IC)	**	NS	**	**
SC vs. IC-I	**	NS	**	**
SC vs. IC-II	**	NS	*	**
IC-I vs. IC-II	NS	NS	*	NS
LSD (0.05)				
Inter crop (IC)	3.8	0.7	0.2	1.2
Nitrogen Split (NS)	1.3	0.3	0.1	0.7
IC x NS	NS	NS	NS	NS

Means within a category followed by different letters are different (p≤0.05) using LSD test.
**Nitrogen Split Application (NS); NS_1: 50% at seedbed and 50% at tillering (70DAS) of the recommended 120 kg N ha⁻¹; NS_2: 25% at seedbed, 50% at tillering (70DAS) and 25% at anthesis (110 DAS); NS_3: 25% at seedbed, 25% at tillering (70DAS) and 50% at anthesis (110 DAS).*

Biomass and yield (kg ha⁻¹)

Data regarding biomass of wheat was affected by different NS as well as IC and their interaction (Table 3). Wheat biomass did not change with NS_1 and NS_2 but did increase with NS_3. None of the intercrop showed at par biomass as observed for the sole wheat crop. Wheat intercropping with any of the proposed species showed a strong reduction in biomass of wheat. For planned mean comparison, the sole vs. IC, sole vs. IC-I, sole vs. IC-II and IC-I vs. IC-II were found significant for wheat biomass. Data regarding grain yield of wheat as affected by different NS and intercropping are presented in Table 4. Among NS, the NS_1 did not differ than NS_2 for grain yield of wheat crop. However, NS_3 shower higher grain yield than NS_2. Among the intercrop (IC), none of the IC showed higher yield than sole wheat crop. Nonetheless, wheat-fababean was found better than any other IC combination for wheat grain yield. Planned mean comparison showed significant effect on grain yield of sole vs. IC, sole vs. IC-I, sole vs. IC-II, IC-I vs. IC-II. Harvest index of wheat was significantly affected by NS and intercropping (Table 5). Treatment NS_3 showed the higher harvest index of wheat than rest of the NS. Among the intercropping, the wheat-sunflower IC-I showed at par harvest index of wheat with sole and the rest a decrease. Planned mean comparisons were significant for harvest index of sole vs. IC, sole vs. IC-I and sole vs. IC-II. Wheat intercrop with other species has strengthened the wheat canopy against lodging at the time of close to maturity. Moreover, the NS is of great interest in terms of grain yield and soil fertility for grain development to be used for the good backing quality with desirable protein content and the soil sustainability issue for the following crops in rotation on the piece land. It is clear from the Figure 2 that sole wheat was incomparable for grain yield with any

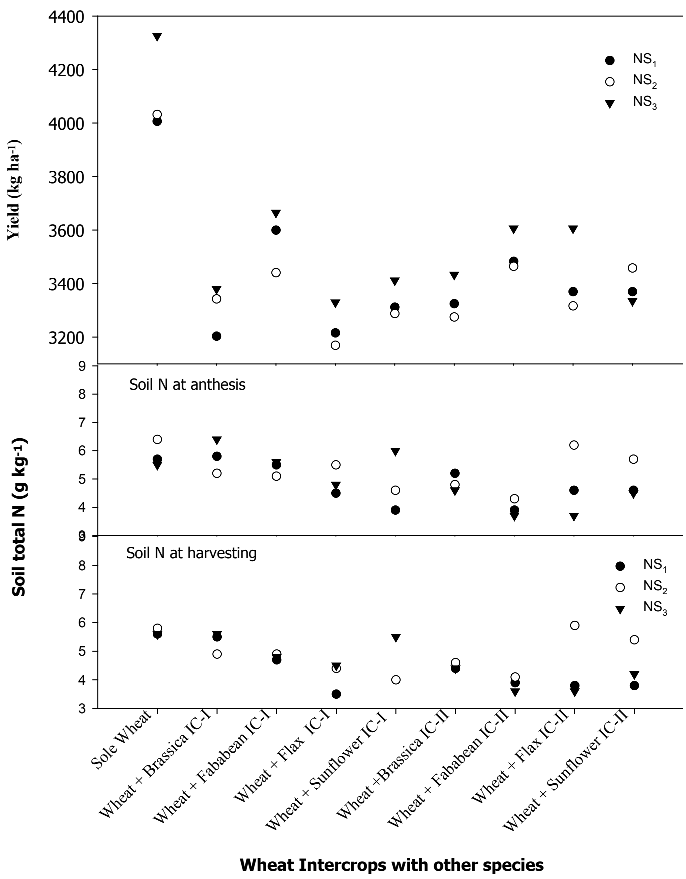

Figure 2: *Relationship of soil total N at sowing, anthesis and crop harvest of field remains under wheat for grain yield (kg ha⁻¹) with N split application (NS) for intercropped with other species.*

Table 3: *Biological yield (kg ha^{-1}) of wheat crop as influenced by sole vs. intercrop (IC) and N-split application (NS) during the crop growth.*

Crops	N-Split Application (NS)			Mean
	NS_1	NS_2	NS_3	
Sole Wheat	12033.3	11670.7	11378.0	11694.0 a
Wheat + Brassica IC-I	9675.0	9333.3	9990.7	9666.3 f
Wheat + Fababean IC-I	11316.7	10533.3	10441.7	10763.9 b
Wheat + Flax IC-I	10116.7	10018.3	10185.7	10106.9 de
Wheat + Sunflower IC-I	9291.3	9400.0	10157.7	9616.3 f
Wheat +Brassica IC-II	9754.0	9955.7	10275.0	9994.9 e
Wheat + Fababean IC-II	9960.3	10433.3	10604.3	10332.7 c
Wheat + Flax IC-II	10125.0	10108.3	10604.3	10279.2 cd
Wheat + Sunflower IC-II	10125.0	10658.3	10263.3	10348.9 c
Mean	10266.4 b	10234.6 b	10433.4 a	
Planned mean comparisons	SC	IC	Significance	
Sole crop (SC) vs. Intercrop (IC)	11694.0	10136.1	***	
SC vs. IC-I	11694.0	10038.4	***	
SC vs. IC-II	11694.0	10233.9	***	
IC-I vs. IC-II	10038.4	10233.9	**	
LSD (0.05)				
Inter crop (IC)	212.3			
Nitrogen split application (NS)	133.5			
IC x NS	***			

Means within a category followed by different letters are different (p≤0.05) using LSD test.
**Nitrogen Split Application (NS); NS_1: 50% at seedbed and 50% at tillering (70 DAS) of the recommended 120 kg N ha^{-1}; NS_2: 25% at seedbed, 50% at tillering (70 DAS) and 25% at anthesis (110 DAS); NS_3: 25% at seedbed, 25% at tillering (70 DAS) and 50% at anthesis (110 DAS).*

of the intercrops i.e. IC-I and IC-II with any selected species. Nonetheless, among the IC, wheat-fababean showed better yield performance for IC-I and IC-II than rest of the species with wheat crop. Soil total N content at anthesis was higher for sole wheat as well as for IC-I with exceptionally for wheat-flax and wheat-sunflower IC-II at NS_2. Figure at anthesis and maturity stages showed variations for soil total N. The highest soil N were observed for sole wheat with NS_2, followed by Wheat Brassica and Wheat fababean. The rest intercrops showed a reduction in soil total N at anthesis as well as at maturity for sustainable land use. Contrary to this, NS_3 showed higher soil total N for all IC-I treatments when compared with IC-II for any species at anthesis stage of wheat growth and development. Treatment NS_1 did not perform as good as the NS_2 or NS_3 for sole and/or IC for soil total N at anthesis. Likewise, the soil total N at maturity stage of the wheat crop is of great interest of the study to compare sustainability of land for the next crop in rotation. Wheat with brassica and fababean as IC-I are the best options as wheat intercrop for future climate change in the region to sustain higher soil total N with wheat desire grain yield.

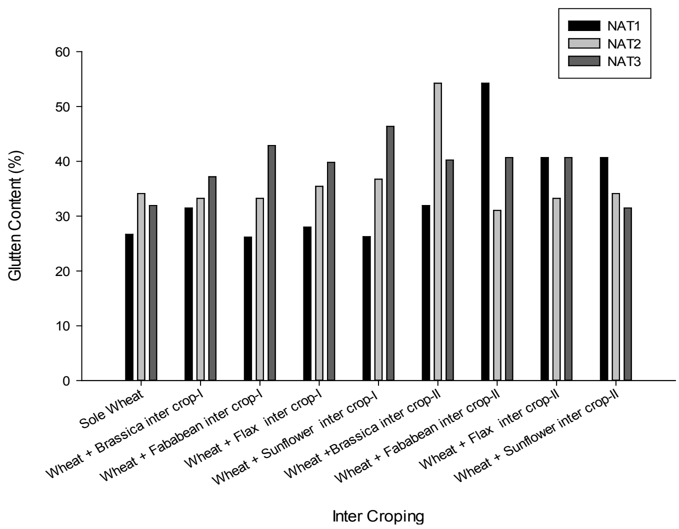

Figure 3: *Wet gluten content (%) as affected by Nitrogen split application (NS) i.e.* **NS_1**: *50% N at seed bed and 50% N at tillering (70DAS) of the recommended 120 kgha^{-1} (right dark bars); NS_2: 25% N at seedbed; 50% N at tillering (70DAS) and 25% N at anthesis (110 DAS) (light central bars); NS_3: 25% N at seedbed, 25% N at tillering (70 DAS) and 50% N at anthesis (110 DAS) to wheat crop (left gray bars).*

Wet gluten content (%)

Data regarding wet gluten content (%) of wheat are shown in Table 6. Statistical analysis of data indicated significant effect for NS with higher for the NS_2 than NS_1. Nonetheless, NS_2 and NS_3 did not differ in wet gluten content from each other. For intercropping wet gluten content for sole wheat were at par with all intercrops of other species as IC-I and IC-II except the wheat-brassica. Interactive response on wet gluten content was non-significant for any possible planned means. Interactive effect of the treatments (NS and wheat-IC) showed the best gluten for the wheat intercropped with fababean (IC-I and II) for NS_1 and NS_3 for rest of the maximum wheat intercrop with rest of the species but sunflower (Figure 3).

Table 4: *Grain yield (kg ha^{-1}) of wheat crop as influenced by sole vs. intercrop (IC) and N-split application (NS) during the crop growth.*

Crops	N-Split Application (NS)			Mean
	NS_1	NS_2	NS_3	
Sole Wheat	4006.3	4032.0	4326.0	4121.4a
Wheat + Brassica IC-I	3203.3	3342.7	3380.0	3308.7d
Wheat + Fababean IC-I	3599.7	3440.7	3665.0	3568.4b
Wheat + Flax IC-I	3215.7	3169.3	3329.7	3238.2e
Wheat + Sunflower IC-I	3312.0	3288.0	3412.0	3337.3cd
Wheat +Brassica IC-II	3325.0	3275.0	3433.3	3344.4cd
Wheat + Fababean IC-II	3483.3	3464.7	3606.0	3518.0b
Wheat + Flax IC-II	3370.0	3316.7	3606.0	3430.9c
Wheat + Sunflower IC-II	3370.0	3458.3	3335.0	3387.8cd
Mean	3431.7b	3420.8b	3565.9a	
Planned mean comparisons	SC	IC	Significance	
Sole crop (SC) vs. Intercrop (IC)	4121.4	3386.2	***	
SC vs. IC-I	4121.4	3363.2	***	
SC vs. IC-II	4121.4	3409.1	***	
IC-I vs. IC-II	3363.2	3409.1	*	
LSD (0.05)				
Inter crop (IC)	69.5			
Nitrogen split application (NS)	43.7			
IC x NS	*			

Means within a category followed by different letters are different (p≤0.05) using LSD test.
**Nitrogen Split Application (NS); NS_1 = 50% at seedbed and 50% at tillering (70 DAS) of the recommended 120 kg N ha^{-1}; NS_2: 25% at seedbed, 50% at tillering (70 DAS) and 25% at anthesis (110 DAS); NS_3: 25% at seedbed, 25% at tillering (70 DAS) and 50% at anthesis (110 DAS).*

Table 5: *Harvest index (%) of wheat crop as influenced by sole vs. intercrop (IC) and N-split application (NS) during the crop growth.*

Crops	N-Split Application (NS)			Mean
	NS_1	NS_2	NS_3	
Sole Wheat	33.3	34.6	38.0	35.3 a
Wheat + Brassica IC-I	33.1	35.8	33.8	34.3 b
Wheat + Fababean IC-I	31.8	32.7	35.1	33.2 c
Wheat + Flax IC-I	31.8	31.6	32.7	32.0 d
Wheat + Sunflower IC-I	35.7	35.0	33.6	34.8 ab
Wheat +Brassica IC-II	34.1	32.9	33.4	33.5 b
Wheat + Fababean IC-II	35.0	33.2	34.0	34.1 b
Wheat + Flax IC-II	33.3	32.8	34.0	33.4 c
Wheat + Sunflower IC-II	33.3	32.5	32.5	32.7cd
Mean	33.5b	33.5b	34.1a	
Planned mean comparisons	SC	IC	Significance	
Sole crop (SC) vs. Intercrop (IC)	35.3	33.4	***	
SC vs. IC-I	35.3	33.6	***	
SC vs. IC-II	35.3	33.3	***	
IC-I vs. IC-II	33.6	33.3	ns	
LSD (0.05)				
Inter crop (IC)	0.9			
Nitrogen split application (NS)	0.6			
IC x NS	***			

Means within a category followed by different letters are different (p≤0.05) using LSD test.
**Nitrogen Split Application (NS); NS_1: 50% at seedbed and 50% at tillering (70 DAS) of the recommended 120 kg N ha^{-1}; NS_2: 25% at seedbed, 50% at tillering (70 DAS) and 25% at anthesis (110 DAS); NS_3: 25% at seedbed, 25% at tillering (70 DAS) and 50% at anthesis (110 DAS).*

Data pertaining emergence and days to emergence is independent to treatments sole and IC as well as NS, therefore did not show any change (Le-Gious et al., 1999). However, IC and NS had a positive effect on days to anthesis. Wheat intercrop with fababean and NS_3 took the maximum days to anthesis for accelerated vegetative growth by N availability as well as fixed to delay maturity (Gungula et al., 2008; Song et al., 2007). Plant height was significantly affected by IC and NS. The IC-II produced taller plants as well as NS_3 which might be the N availability in splits for the plant demand with age in advancement as well as spacing of IC-II than IC-I or sole wheat (Jan et al., 2002; Naveed et al., 2013). In research work conducted by Khan et al. (2005) increased plant height of wheat observed for wheat intercrop with chickpea due to N fixation and availability during growth phase of wheat crop. Tiller per unit area of wheat is independent of species and N, therefore did not show any changes (Ali et al., 2005). Grain yield is the major objective of growing wheat for staple food in Pakistan and rest of the world. Yield increase with any treatments is subject to improve its major yield traits. For wheat the yield contributing traits are grain spike^{-1}, spike length, spike number and grain weight. If any of the given traits increased a significant change in yield is expected (Khatun et al., 2012). Spike length is important for the wheat to have higher harvest index and hence the grain yield (Martre et al., 2003). Split N application with desired quantity for plant extends its effective utilization by crop during its growth and development and hence also produced healthy traits with little or no losses from the soil (Malik et al., 2002). Longer spike with higher grains also ensured greater weight of the spike and hence yield (Khalil et al., 2011). Maximum splits over single application has proven better for crop but the expected climate change scenario of the region appropriate splits N is essential to be investigated for the major crops like wheat which is grown at higher acreages annually and its N demand is also increasing due to introduction of the high yielding varieties (Mohammad et al., 2009; Naveed et al., 2013). Higher N content at anthesis in soil ensures optimum N in grain that also suits well for the baking products for wheat grown in the region (Khatun et al., 2012). Thousand grain weight was higher in wheat-fababean intercrop as well as NS_3 which was due to sufficient at the time of grain development in wheat (Zulfiqar et al., 2000) and may also be N-fixation capacity of fababean (Song et al., 1998). Moreover, it was observed that fababean is more compatible with wheat crop canopy as companion crop due to its growth in intercropping when compared with results of other species as IC-I and IC-II.

Grain yield was affected by IC and NS with maximum for the sole wheat. It is clear that wheat sole under irrigated condition is incomparable with any intercrop. Nonetheless, intercrop is second option for region where wheat is adversely affected by heavy winds at the time of close to maturity with lodging. Yield reduction of 20-50% has been observed in wheat crops lodged when irrigated close to maturity or rain showers reported in current climate change scenarios (Shahzad et al., 2007). Treatment NS_3 gave the highest yield due to its maximum utilization by crop against losses (Abedi et al., 2011). Harvest index influenced for IC and NS. Highest harvest index noticed in wheat followed by wheat-sunflower IC-I. Treatment NS_3 showed better harvest index due to healthy traits. Data concerning gluten content was significantly influenced by NS and IC with higher for NS_3 and NS_2. Grain protein in wheat is based on N rates and availability at the time of grain development (Nakano et al., 2008). Composition of grain gluten may be affected by factors, soil N fertilizer status at grain growth and development (Saint et al., 2008). Higher grain gluten is considered the best for bread making and hence is directly related with the maximum N in soil during grain development. Splits application in three than two showed better gluten and hence could be ranked best for bread (Olowe and Adeyemo, 2009).

Table 6: *Wet gluten content (%) of wheat crop as influenced by sole vs. intercrop (IC) and N-split application (NS) during the crop growth.*

Crops	N-Split Application (NS)			Mean
	NS_1	NS_2	NS_3	
Sole Wheat	34.0	33.0	34.0	33.7 a
Wheat + Brassica IC-I	31.0	33.0	32.3	32.1 b
Wheat + Fababean IC-I	31.0	33.0	35.0	33.0 ab
Wheat + Flax IC-I	27.7	35.0	36.3	33.0 ab
Wheat + Sunflower IC-I	31.3	36.0	35.7	34.3 a
Wheat +Brassica IC-II	32.3	35.3	35.0	34.2 a
Wheat + Fababean IC-II	35.3	30.7	36.0	34.0 a
Wheat + Flax IC-II	34.3	33.0	36.0	34.4 ab
Wheat + Sunflower IC-II	34.3	33.7	31.0	33.0 ab
Mean	32.4b	33.6a	34.6a	
Planned mean comparisons	SC	IC	Significance	
Sole crop (SC) vs. Intercrop (IC)	33.7	33.4	Ns	
SC vs. IC-I	33.7	33.1	Ns	
SC vs. IC-II	33.7	33.7	Ns	
IC-I vs. IC-II	33.1	33.7	Ns	
LSD (0.05)				
Inter crop (IC)	Ns			
Nitrogen split application (NS)	0.7			
IC x NS	***			

Means within a category followed by different letters are different ($p \leq 0.05$) using LSD test.
**Nitrogen Split Application (NS); NS_1: 50% at seedbed and 50% at tillering (70 DAS) of the recommended 120 kg N ha^{-1}; NS_2: 25% at seedbed, 50% at tillering (70 DAS) and 25% at anthesis (110 DAS); NS_3: 25% at seedbed, 25% at tillering (70 DAS) and 50% at anthesis (110 DAS).*

Conclusions and Recommendations

From the study, it is concluded that N-applications splits (i.e. NS_2 and NS_3) were effective for wheat over the recommended two splits (i.e. NS_1) for higher grain yield and quality. Split N (viz. NS_2 and NS_3) are more effective to overcome during the crop growth as N is mobile and with increase precipitation amount at climate change scenarios may fails to produce quality grains for good baking Nonetheless, higher soil total N at harvest of NS_2 i.e. three splits; 25% seedbed, 50% tillering and 25% anthesis expressed better sustainable soil management under cereal based cropping. Intercrop wheat with fababean is of great potential to minimize lodging issue over the sole wheat in areas where wind is becoming an issue of changing climate in the future.

Author's Contribution

M. Salman Wazir conducted research and drafted manuscript. M. Akmal developed the idea and edited the manuscript.

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