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Full Length Article

Preceding Cropping and Nitrogen Effects on the Performance of Rainfed Wheat

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Abstract

A cropping pattern of growing cereals after cereals in the arid area has further depleted the soil fertility. Improving or maintain fertility at existing level is possible through the changes in the existing cropping pattern as the farmers of dry land do not have the tradition and capacity to use costly fertilizers. A set of experiments were conducted at New Developmental Farm, Khyber Pakhtunkhwa Agricultural University Peshawar, Pakistan during 2008-2010 to evaluate the effect of preceding cropping pattern and nitrogen application effect on rainfed wheat. Wheat variety Pirsabak-2005 was sown in a randomized complete block design with split plot arrangement, having three replications. Wheat was planted after the previous cropping patterns i.e., millet, sorghum, sesame, mungbean, guar and groundnut as sole and each in combination with groundnut were repeated for two consecutive years (2008-2010). Cropping pattern was allotted to main plot and current application of three levels of nitrogen (0, 45 and 90 kg ha^{-1}) to subplots. The results showed that cropping pattern of legumes (sole) as preceding crops has retained more soil N as compared with non-legumes(sole) followed by the groundnut+ sesame. Planned mean comparison exhibited that plots sown with legumes crops (groundnut, mungbean and guar) produced higher grain yields of wheat crop. Higher response of wheat to N application by the preceding cropping pattern of groundnut + sesame, groundnut + mungbean or sesame (sole) was observed. Significant increase in the grain yield and yield component were observed with application of N. As both soil N reserve and grain yield increased by preceding legumes (sole) or groundnut+ sesame, growing of legumes (sole) or intercropping of legumes+ sesame than cereal (sole) as preceding crop is suggested. N application of 45 kg ha^{-1} to rainfed wheat having legume as preceding crop is recommended.

Keywords: *Triticum aestivum* L.; Cropping pattern; Nitrogen; Yield

Introduction

Plants nutrient deficiencies (Rashid, 1994) in general and nitrogen (Rashid and Qayyum, 1991) in particular are amongst the major factor limiting cereals production (Shah *et al*., 2003) in Pakistan. Lower use efficiency of nitrogen (N) either because of leaching, volatilization, immobilization and de-nitrification, has observed worldwide (Zapata and Cleenput, 1986; Idris and Mohammad, 2001). The situation is more critical in the dryland areas with predominantly cereal based cropping pattern where commercial fertilizer application is almost negligible. Lower biomass production because of the meager precipitation and continuous growing of cereal without proper crop rotation has further depleted soil nitrogen reserves and is continued at alarming rate. The exhaustion of nutrients reserve has caused a very serious threat to overall rainfed agricultural lands productivity in Pakistan (Sultani, 2004). The sustainable way to enhance soil N reserve is to grow those leguminous crops that are adapted to the rainfed area. The effect of legume on grain yield is quantified in terms of yield obtained in monoculture (Peterson and Varvel, 1989; Dalal *et al*., 1998). The positive effects of crop rotation and intercropping over cereal monocultures are well-documented. Crop rotation can improve soil structure and fertility (Carroll *et al*., 1997) and generally legumes fixes about 15-210 kg N ha^{-1} seasonally. Chalk (1991) reported that the legumes generally contribute 40 kg N ha^{-1} to succeeding crop. The presence of other plants of the same or different species modified the growth and development of plants, under field conditions due to the allelopathy and competition (Rice, 1984; Farooq *et al*., 2011). Buildup of phytotoxins and harmful microbes in soil are resulting in phytotoxicity and soil sickness problem due to continuous monocultures have been reported by Narwal (2004). Wu *et al*. (1999) were of the opinion that reliance on traditional herbicides in crop production can be reduced by growing crops having allelopathic properties and reducing pollution as crops are easily biodegradable and less polluting than the traditional herbicides.

However, exploitation of this biological N is dependent on various factors like environment, nutritional status of soil and also the cropping pattern in use (Dakora and Keya, 1997). Crops with allelopathic properties may

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suppress subsequent crop growth. Cereals cover crops with high carbon to nitrogen ratio may immobilize soil N allowing N-fixing crops to be more competitive (Frick and Johnson, 2012). Keeping in view the importance of cropping pattern and its effect on N status of soil the present experiments were conducted. The aim of the study was to minimize reliance on the use of commercial fertilizers in the rainfed by shifting from the growing of cereal(sole) to intercropping and preferably legumes intercropping with other high value crop(sesame) as preceding crop than cereal as sole or intercropping. Six major crops i.e. groundnut (*Arachis hypogea* L.), guar (*Cyamopsis tetragonoloba* L.) mungbean (*Vigna radiata* L.), millet (*Pennisetum typhoides* L.), sorghum (*Sorghum bicolor* L.) and sesame (*Sesamum indicum* L.) that are already adapted to the project area were grown as sole or intercropped as preceding crops in summer. Its effect on the coming season wheat (winter) in addition to current application of N level was evaluated and is reported here.

Materials and Methods

A set of field experiments were conducted at New Developmental Farm of Khyber Pakhtunkhwa Agricultural University, Peshawar Pakistan, during winter 2008-2010. The experimental site is located at latitude of 34 ^{0}N and 354.3 m altitude. The area is mainly dry with mean annual precipitation of 441 mm having warm to hot, semi arid, sub tropical, continental climate. The mean maximum temperature in summer is 40°C and the mean minimum temperature is 25°C, while in winter mean maximum temperature is 18°C and mean minimum temperature is 4°C (Dept. of Meteorology, Pakistan).

The soils have been developed in piedmont alluvium and are clay loams. Rainfall data (Table 1) shows that on the basis of crop seasons there was less rainfall in wheat growing months (Oct-April) barely approaches 50 mm as compared with preceding summer crops (May- Sept) where seasonal rainfall exceeds 200 mm. Year 2009 was the driest year when compared with long period of 30 years as well as to the years 2008 and 2010.

In summer (May, 2008) after harvest of wheat, six crops (millet, sorghum, sesame, mungbean, guar and groundnut) were grown as sole and intercropped with groundnut. After harvest of these six crops in October, 2008, the field was kept fallow during the winter season (October, 2008-April, 2009). In May, 2009 all the above summer crops were sown on the already established plots of year 2008. Instead of leaving the field as Fallow for the second year, wheat was sown in winter (October, 2009) and harvested in- May 2010. Herbicides were applied to control the weed during the winter fallow as well as in wheat growing period. Nitrogen at the rate 0, 45 and 90 kg ha^{-1} was applied to wheat crop at the time of sowing. The crops were grown under rainfed conditions. Irrigation was only applied at the time of wheat sowing Soil N contents were followed during the course of experiment (prior to sowing and after wheat harvest). Six composite sampling before sowing (at start of experiments) were collected up to the depth of 30 cm for N determination as baseline or bench mark. There-after soil samples were collected on sub plot basis. These soil sampling were taken at depth of 0-30 cm from three spots within each sub plot and were thoroughly mixed. The sampling were air dried, finely ground sieved through <0.2 mm and analyzed for total N. Nitrogen concentration in soil was determined by Kjeldhal method (Bremner and Mulvaney, 1982). The experiment was carried out in randomized complete block design (RCBD), with split plot arrangement, having three replications. Cropping pattern was allotted to main plot (5 m × 6.4 m) while nitrogen levels were allotted to sub plot (5 m × 1.8 m). Row to row distance for wheat was 30 cm. Wheat varieties Pirsabak-2005 was grown at the seed rate of 80 kg ha^{-1} at proper moisture condition. Phosphorous as P_2O_5 was applied at the rate of 60 kg ha^{-1} as basal dose at time of sowing. The crops sown in summer as preceding crops were: three legumes (1) groundnut (*A. hypogea*), (2) guar (*C. tetragonoloba*) and (3) mungbean (*V. radiata*), two cereals (a) millet (*P. typhoides* L.) and (b) sorghum (*Sorghum bicolor* L.) and one oil seed crop i.e., sesame (*Sesamum indicum* L.), which is non cereal/non leguminous crop. Eleven cropping pattern having the following rotations were studied.

Cropping pattern (CP)	Two years rotation sequence
1	Groundnut Sole –Fallow- Groundnut Sole-Wheat
2	Mungbean Sole –Fallow-Mungbean Sole-Wheat
3	Guar Sole- Fallow-Guar Sole-Wheat
4	Millet Sole- Fallow-Millet Sole-Wheat
5	Sorghum Sole- Fallow-Sorghum Sole-Wheat
6	Sesame Sole- Fallow-Sesame Sole-Wheat
7	Groundnut+Mungbean-Fallow-Groundnut+Mungbean-Wheat
8	Groundnut+Guar-Fallow-Groundnut+Guar-Fallow-Wheat
9	Groundnut+Millet–Fallow-Groundnut+Millet-Fallow-Wheat
10	Groundnut+Sorghum-Fallow-Groundnut+Sorghum-Wheat
11	Groundnut+ Sesame-Fallow-Groundnut+Sesame-Wheat

Data were analyzed statistically according to RCB design with split plot arrangement using Fishers Analysis of Variance Techniques. Least significant difference (LSD) test at 5% probability level was employed upon obtaining significant differences among treatments means (Steel *et al*., 1997).

Results

Soil analysis (Table 2) shows the composite sampling taken before the start of experiment (Initial N) had 211 mg kg^{-1} of N. Soil sample collected from individual plots after two cycles of the cropping pattern but before the sowing wheat (Summer N) reveals that growing of cereals (millet and sorghum) as sole for two consecutive years had reduced the N contents from the base line of 211 mg kg^{-1} of N but had not altered the soil N reserve when intercropped with groundnut during the same period. Soil N remains stable when sesame crop was grown as

Table 1: Rainfall (mm) during the years 2008 -2010 and 30 years average of the study area

Period	2008	2009	2010	30 years average
October to April	22	25	50	50
May to September	198	75	230	250
Annual	210	105	280	300

Table 2: Effect of cropping pattern on soil N contents (mg kg^{-1}) during the course of experiment (2008-2010)

Cropping pattern	Initial N	Summer N	Final N
Sole Millet	211	185	172
Sole Sorghum	211	188	176
Sole Sesame	211	214	193
Sole Groundnut	211	268	259
Sole Mungbean	211	374	365
Sole Guar	211	360	348
Groundnut + Mungbean	211	364	351
Groundnut + Guar	211	389	376
Groundnut + Millet	211	215	210
Groundnut + Sorghum	211	217	210
Groundnut + Sesame	211	355	273

Table 3: Numbers of spike bearing tillers and grains per spike of wheat as affected by preceding cropping pattern and N levels

Cropping pattern (CP)	Spikes bearing tillers				Grains per spike			
	Nitrogen Applied (kg ha^{-1})				Nitrogen Applied (kg ha^{-1})			
	0	45	90	Mean	0	45	90	Mean
Groundnut (sole)	162	166	174	168	34.0	37.6	38.3	36.6 a
Mungbean (sole)	171	179	184	178	35.3	40.7	40.9	38.9 a
Guar (sole)	162	169	171	167	35.3	37.6	38.7	37.2 a
Millet (sole)	160	172	176	169	28.7	32.4	34.4	31.9 cb
Sorghum (sole)	164	178	188	177	28.7	35.0	35.0	32.9 b
Sesame (sole)	173	179	182	178	34.5	34.4	34.8	34.6 a
Groundnut + Mungbean	164	168	170	167	32.0	32.7	34.0	32.9 b
Groundnut + Guar	167	172	175	171	34.3	34.4	36.7	35.1 a
Groundnut + Millet	159	167	174	167	30.5	37.6	38.7	35.6 a
Groundnut + Sorghum	168	177	184	176	29.7	39.1	39.7	35.6 a
Groundnut + Sesame	169	178	184	177	32.6	33.6	34.7	33.1 bc
Mean	165 a	173 ab	178 a		32.3 b	36.1 a	37.1 a	

Table 4: Thousand grains weight (g) and grain yield (Mg ha^{-1}) of wheat as affected by preceding cropping pattern and nitrogen

Cropping pattern (CP)	Thousand grain weight (g)				Grain yield (Mg ha^{-1})			
	Nitrogen Applied (kg ha^{-1})				Nitrogen Applied (kg ha^{-1})			
	0	45	90	Mean	0	45	90	Mean
Groundnut (sole)	25.1	28.5	29.3	27.6 bc	1.13	1.54	1.89	1.52
Mungbean (sole)	26.6	29.9	31.7	29.4 a	1.65	1.85	2.22	1.91
Guar (sole)	26.2	28.4	30.5	28.4 ab	1.20	1.70	1.99	1.60
Millet (sole)	23.0	24.1	24.4	23.8 d	0.88	1.18	1.34	1.13
Sorghum (sole)	21.3	24.3	26.6	24.1 d	0.95	1.44	1.62	1.34
Sesame (sole)	22.2	23.2	27.5	24.3 d	1.11	1.51	1.67	1.43
Groundnut + Mungbean	22.5	24.3	25.4	24.1 d	1.44	1.67	1.95	1.69
Groundnut + Guar	23.9	28.4	31.4	27.9 bc	1.23	1.52	1.88	1.54
Groundnut + Millet	23.2	27.8	28.5	26.5 bc	0.99	1.38	1.76	1.37
Groundnut + Sorghum	23.2	26.9	29.6	26.6 bc	1.07	1.65	1.76	1.49
Groundnut + Sesame	24.1	28.3	30.1	27.6 bc	1.21	1.49	1.75	1.48
Mean	23.8 a	26.7 b	28.6 a		1.17 b	1.54 ab	1.80 a	

Means followed by different letters within same category are significantly different at 5% probability level using LSD

sole; however, significant increase in N contents of plots sown with sesame+groundnut was recorded. Legumes (sole) or intercropped with groundnut had remarkable increase in N contents. The N measured at the termination of experiment (Final N) shows that it followed the same trend as was seen for summer N with the exception that its N contents were lower than the N measured during the summer(before wheat sowing).

Numbers of spike were not significantly affected by preceding cropping pattern however the effect of N levels

Table 5: Planned mean comparison of spike bearing tillers, grains per spike, 1000 grains weight and grain yield of wheat as affected by preceding cropping pattern and nitrogen levels

Planned Mean Comparison	Spike bearing tillers (m^{-2})	Grains per spike	Thousand grain weight (g)	Grain yield (Mg ha^{-1})
Legume vs	171^{ns}	37.6^{ns}	28.5*	1.7*
Non-legume	175	33.1	24.1	1.3
Legume vs	171^{ns}	37.6*	28.5*	1.7*
Cereal	173	32.4	23.9	1.2
Legume vs	171^{ns}	37.6^{ns}	28.5*	1.7*
Sesame	178	34.6	24.3	1.4
Cereal vs	173^{ns}	32.4^{ns}	23.9^{ns}	1.2*
Sesame	178	34.6	24.3	1.4

*= significant and ns = non-significant at 5% level of probability
Legume= (groundnut, mungbean and guar); Non legumes= (millet, sorghum and sesame)
Cereals= (millet and sorghum)

were significant (Table 3). Increase in the spike with increase in N was generally observed. Plots without N application had lower spikes as compared with 90 kg ha^{-1} although it was at par with 45 kg ha^{-1} N supply. Grains per spike of wheat were significantly affected by preceding cropping pattern and nitrogen (Table 3). Sole growing of groundnut, mungbean, gaur and sesame or the combination of groundnut+ guar, groundnut+ millet and groundnut+ sorghum had significantly more grains per spike. Spike increased with N application when compared with control; however the difference between the two levels of N was not significant. Planned mean comparison (Table 5) reveals that legumes as preceding cropping had significantly increase grain $spike^{-1}$ of wheat as compared with cereals.

Response of grains weight to the preceding cropping pattern and nitrogen is given in Table 4. Means value of the table shows that mungbean and guar grown as sole had significantly more grain weight, while millet, sorghum and sesame as sole had the lowest grain weight. Application of N had significantly increased grain weight as compared with control and increased with increase in N. Planned mean comparison (Table 5) shows that plots devoted to the legumes as preceding crops had significantly heavier grains as compared with group of non-legumes and cereals. Poor response in grain weight can be seen for millet (sole), sorghum (sole) and sesame (sole), while their combination with legumes responded well to N application and finally produced heavier grains (Table 4).

Mean data pertaining to grain yield (Mg ha^{-1}) as affected by preceding cropping pattern and nitrogen is presented in Table 4. Statistical analysis of data showed that, the effect of preceding CP and N was significant. Mungbean (sole) as preceding crop produced highest grain yield of wheat (1.9 Mg ha^{-1}), while millet plots had the lowest grain yield of 1.3 Mg ha^{-1}. Planned mean comparison (Table 5) showed that legumes as preceding cropping pattern had significantly higher grain yield (1.7 Mg ha^{-1}) than the cereals and sesame (1.2 Mg ha^{-1}). This increase in wheat grain yield obtained from legumes sown plots was mainly due to significant increase in its grains $spike^{-1}$ and grain weight. Sesame had produced higher grain yield than cereals but its yield was lower than legumes sown plots. Comparing differences within the cereal group, millet as sole had lower grain yield than sorghum (sole). Among legumes group, mungbean as sole out yield when compared with other legumes irrespective of the fact it were grown as a sole or intercropped with groundnut. Sesame (sole) plots had lower grain yield than legumes group but higher than cereals. Among intercropping, groundnut+ mungbean had the highest while groundnut + millet had the lowest grain yield of wheat. Nitrogen level had significant effect on grain yield as it increased with increase in N levels from 0 to 90 kg ha^{-1}.

Discussion

Low soil fertility status and non availability of moisture at the proper time and amount is common feature of dryland agriculture. Rainfall data (Table 1) shows that in three years of the experiment the rainfall was lower than the long term mean data (30 years). Lower rainfall in winter (October-April) is not surprising because of the Monsoon rainfall pattern at the site (May-Sept). Year 2009 had the lowest rainfall as compared with others. Soil N reserves during the three years of the experiment had increased or were brought back to the base level by including the legumes against the existing cereal (sole) based cropping pattern in the project area (Table 2). The soil N contents have increased from initial 211 mg kg^{-1} to 389 mg kg^{-1} depending upon the nature of the crops and the way they were grown (Table 2). The cereals group (millet and sorghum) as usual had depleted N from its base line when grown as sole and hardly regains its initially N contents when intercropped with groundnut. Plots grown with sesame + groundnut had significantly improved soil N reserve as compared with cereals however sesame response was lower than the legumes group irrespective of its cropping pattern. Sesame as sole neither depleted nor improved N but had increased N form 211 to 355 mg kg^{-1} (almost 40% increase) when intercropped with groundnut. Significant increase in N contents with legumes as sole or combination with groundnut was observed. The increase in N reserve with legumes in the cropping pattern is well documented (Hossain *et alet al*., 1996; Kumbhar *et al*., 2007; Hayat *et al.*, 2008; Porpavai *et al*., 2011) however little information is available on the response of sesame a dryland crop to the different cropping system.

The effect of cropping pattern on two yield components of wheat (number of grains per spike and grain weight) was significant. Planned means comparison (Table 5) shows that legumes grown plots had higher grain yield of succeeding crop because of the increase in yield components particularly grains per spike, grain weight and are in agreement with those of Sadiq (2008), Kumbhar *et al.* (2007), Evens *et al*. (1991) and

Singh and Singh (2000). Sesame grown plots had also improved wheat grain number more than those of cereals indicating that sesame could be a better choice as compared with cereal after legumes in the cropping system in term of improving yield and the least adverse effect on soil N status. Final grain yield was significantly lower in cereal group (sole) sown and highest in legumes (sole). Intercropping has improved the grain yield of cereal as well as sesame. Increase in grain yield in intercropping of sorghum and millet over its sole growing was 6% and 7%, respectively.

Yield components of wheat were significantly affected by N levels. Grain yield of wheat improved with increase in nitrogen level in our study (Table 4). The increase in number of spikes m^{-2} with the increase in nitrogen levels can be attributed to increase in number of fertile tillers with incremental nitrogen (Ayoub *et al.*, 1994; Palta and Fillery, 1995). It may be due to the fact that nitrogen increases grain filling duration (Eichenaur *et al*., 1986), increases net assimilation rate (Sage and Pearcy, 1987), encouraged tillers, grain weight and grains per spike (Qamar *et al.*, 2012). The results are in conformity with Al-Abdulsalam (1997), Bellido *et al*. (2000), Maqsood *et al*. (2000) and Fallahi *et al*. (2008) who reported that grain yield of wheat increased with application of nitrogen.

Significant CP x N interaction for grain weight shows that with increase in N level grain weight increased in all the preceding cropping imposed (Table 4). Maximum grain weight was recorded for legumes crops, followed by the combined cultivation of other crops with legumes. Grain weight of wheat was highest in plot having mungbean (sole) as preceding crop and this can be attributed to the N reserve of the legumes in general and mungbean (sole) in particular. It indicated that legumes not only increased the N reserve of soil but also enhance nitrogen use efficiency as compared with other groups studied here. These findings are in agreement with those of Simpson and Burries *et al*. (1992) who observed that grain yield improved after legumes cropping. Singh *et al*. (1993) attributed the increase in wheat yield after legumes to nitrogen fixation. Russelle (1983) considered it as rotational benefits, and by Reeves and Wood (1994) and Wani *et al.* (1995) it is due to improvement in soil physical, biological properties of the soil. We observed less increase in grain yield of wheat to N levels when the plots were grown with cereal (sole) as preceding crops and is probably because of low initial N soil status and subsequent depletion by the cereals (sorghum and millet) as both the crops are exhaustive crops as compared with legumes. Furthermore it could be due to the allelopathic effect of sorghum as it contains a number of allelochemicals that are against other crops (Roth *et al*., 2000; Sene *et al*., 2001). Plot grown with mungbean or guar as a sole had higher grain yield than its intercropping with groundnut. If sesame has to be grown it would be of worth to grown in association with groundnut and possibly with other legumes.

In conclusion, based on the significant increase in soil N status and grain yield on the subsequent yield of crop (wheat), the sequence of Legume sole>Legumes+Sesame> Legumes+cereal> Sesame+cereal as future cropping pattern is proposed. To be socially acceptable to dryland farmers predominantly having cereal-based cropping pattern, the inclusion of legumes and sesame as intercropping is suggested.

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