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MAIZE AS FODDER UNDER CEREALS BASED ROTATION WITH LEGUME AS CATCH CROP AND MINERAL N

GHULAM HABIB[1], M.F. HASSAN M.F.[2], M. AKMAL[1*], S. AHMAD[1] AND GHUFRANULLAH[2]

**Department of Agronomy, e-mail: akmal_M@hotmail.com*
[1]KPAgricultural University, Peshawar, Pakistan
[2]Livestock Research & Development Farm, Surezai, Peshawar, Pakistan

Abstract

The experiment was conducted to compare *Pigeon pea* (PP) and *Sesbania gentia* (SG) legumes as catch crop in a permanent cereal based (wheat-maize) rotation. The residual effect of legumes with or without added fertilizer (N) was studied on subsequent maize crop grown as fodder. The study aimed to evaluate catch crop response as manure or fodder on the following maize. The results showed that SG was higher in crude protein ($p<0.01$) but lower in crude fiber ($p<0.01$) as compared to PP. The dry matter response of the treatments was almost similar. Maize fodder yield increased by 12.87% and 25.75% with PP and SG, respectively. Added soil N increased maize dry matter by 41.69%. Crude protein (CP) of maize fodder improved by N ($p<0.001$) but slightly decreased with PP and SG ($p<0.05$). Both the PP and SG incorporation as green manure increased maize fodder yield ($p<0.05$). On the other hand, considerable improvement in soil N was also noted when legumes were introduced as compared to fallow treatment. Contrary to that the green manure and/or harvested fodder did not show any significant changes. Results of the present study demonstrated that fallow legume manuring was beneficial in increasing yield of the subsequent crop in rotation and provided extra cover to the soil from erosion in addition to improving soil fertility status.

Introduction

Fodder species and their productivity depend on the area's climate, water availability, rainfall distribution pattern, growth period and soil type (structure, texture) etc. Pakistan presents four seasons: a cool, dry winter (December–February), a hot dry spring (March–May), a summer rainy season or southwest monsoon period (June–September) and the retreating monsoon period (October–November). The onset and durations of seasons vary according to locations and altitudes. Most of the country is generally arid, characterized by hot summers and cool/cold winters, and wide variations between extremes of temperature at given locations. These generalizations should not, however, obscure the distinct differences existing among provinces and particular locations. Country intermittent drought with average annual precipitation varies from >1200 mm in Himalayan sub-mountain area to <150 mm in the south. Mean annual precipitation of 75% occurs in July-September (monsoonal belt).

Fodder crops are cultivated on about 12.5% of the cropped area (Khan *et al*., 2006), which is insufficient to meet current fodder demands of the population (Anon., 2007). According to Hatam *et al.* (2001), more than half of animal feed is coming from fodder crops and crop residues. Grazing, however, contributed in fodder deficiency but of low quality. In last 30 years, area under fodder cultivation has decreased. However, an increase in yield is reported from 17.4 to 23.1 t ha^{-1} (+32.7%) due to research and development. There is great fluctuation in green fodder supply in different seasons particularly in June-July and in November-December leading to a deficiency of approximately 27.29 m t total digestible nutrients (TDN) and 1.68 m t crude protein (Khan *et al.,* 2006).

Current fodder supply is mainly from sorghum, maize, millet, berseem, oat, mustard and gowara or guar (*Cyamopsis teragonoloba*). Summer fodders are primarily sorghum (*Sorghum bicolour*), maize (*Zea mays*) and millet (*Pennisetum americanum*) with low productivity. Wheat being major staple food is cultivated on 66% cropped area. Similarly, the demands of cereals (maize) grains in poultry feed and other products including human food evolved wheat-maize rotation system. However, summer legume in cropping system is a deficiency at the country level. Although the climatic conditions favours yielding year-round growth of green fodder but still green fodder is acute in June-July. Introduction of legumes as catch crop not only improve existing fodder supply and quality but also contribute in improving soil fertility for the subsequent crop in rotation. The study was therefore designed to investigate the possibility of legume as catch crop in the cropping system and evaluate its effect on the following crop growth.

Material and Methods

The study was conducted at the Livestock Research and Development Farm (LRD), Surezai Peshawar, Pakistan. Experimental site is located 350 m above the sea level. Soil of the experimental site was clay loam with 1.15% organic matter, pH 7.8 and total N 0.089%. Climate was subtropical receiving 500-700 mm precipitation with daily mean temperatures varying from 45±4°C in summer to 10±3°C in winter. Irrigation to the crop was provided through tube well.

Experimental design: The experiment was conducted in a split-plot design. Three main treatments [fallow, *Pigeon pea* (PP) and *Sesbania gentia* (SG)] and two sub-treatments (used as green manure or fodder) were used for the subsequent effect of fodder maize grown with or without N-fertilization and soil status. Soon after harvesting the wheat, field of 125m x 35m was divided in three equal main plots. One of which was left fallow (control), 2nd planted with PP and the 3rd with SG in three replications. After 60 days, half the plot of each treatment was harvested for fodder and the other half was ploughed down as green manure to assess their effect on soil and subsequent maize crop in the rotation. One meter square area was randomly sampled at two different locations to asses the dry matter yield. Fresh matter was oven dried at 70°C until achieved a constant weight achieved. Fodder maize was immediately planted in all three main plots providing 0 and 80 kg ha^{-1} N from urea source. Uniform cultural practices were applied to fodder maize production and harvested at dough stage for green fodder. Soil samples were collected both before and after the residue incorporation in soil and analyzed for organic fertility assessment. Composite soil samples (0-10 cm depth) were taken from each experimental plot randomly before sowing to assess fertility status of the soils. When the maize crop reached to blooming stage (about 67 days after sowing), one m^2 area was randomly selected at three different locations within the subplots and harvested for dry matter yield and fodder quality.

Nutrient composition & soil analysis: Dried samples from each sub-plot were ground and passed through one mm screen. Representative samples were analyzed for dry matter, ash, crude protein and crude fiber contents according to AOAC (Anon., 1990). Soil samples were collected from top 30 cm depth 1st before the experimentation, 2nd at sowing time of maize crop and 3rd upon maize harvesting. Samples were analyzed for total N and soil organic carbon. The organic carbon was determined by Walkley-Black method (Nelson & Sommers, 1982). Total N in soils and plant samples were determined by method described by Bremner & Mulvaney (1982).

Statistics: Data were analyzed with ANOVA using GLM procedure of SAS (Anon., 2000). The data collected during 1st part of the experiment including yield parameters and nutrient compositions of legume were analyzed with one-way ANOVA. The 2nd part data were analyzed according to split-plot design using control, PP and SG as main treatments and harvesting or soil mixing of legumes with or without N-fertilization were split over main treatments. Treatment means were compared with LSD ($p<0.05$).

Results and Discussion

Feeding value of summer legumes: Summer legumes can effectively be used as catch crop in the areas where fodder scarcity is acute due to limited land holding. Nutrient composition of both species e.g., PP and SG can be categorized as good quality fodder with optimum concentrations of protein and mineral matter, however, SG had higher mineral ($p<0.05$) and crude protein (CP) contents ($p<0.01$). Moreover, fodder (33.22 Vs 26.89 t ha^{-1}) and CP yield (994 Vs 769 kg ha^{-1}) were observed higher ($p<0.05$) for SG. Green fodder yield in PP was higher due to high moisture contents in its biomass despite their similar dry matter yield (Table 1). Nonetheless, high stem fraction of PP plants contributed for the high fiber contents. On offering both legumes to lactating cows separately, none of these fodders were consumed by the animals relishly. However, mixing with other seasonal fodder in proportionate (1:3) enhanced intake by the animals. Both legumes (PP and SG) being non-conventional fodder, animal needs some adaptation period to adjust. It is suggested that further feeding trials on different animal species may be carried out for intake as sole and mix feeding practices. Fodder scarcity in the study area is a persistent problem due to prevailing cropping system practices. Growing summer legumes fits well as catch crop in a cereals based rotation (e.g. wheat-maize) which served as green fodder supply source of legume.

Residual effect of legumes on fodder maize: In wheat-maize rotation, the following maize green fodder yield was significantly ($p<0.05$) influenced by legume cultivation as catch crop. SG treatment yielded 21.78% higher ($p<0.05$) maize fodder over the fallow plot which was contributed by 13.98% and 28.12% without and with N application to maize, respectively. Likewise, PP yielded 5.13% higher maize production over fallow plot. No increase in maize fodder was observed by PP amendments without N fertilization. However, N application increased maize yield by 16.15%. Mean dry matter (DM) yield of maize was the highest for SG (4.20 t ha^{-1}) followed by PP (3.70 t ha^{-1}) and on fallow land (3.34 t ha^{-1}). The observations demonstrated the beneficial effect of legumes cultivation as green manure on subsequent maize yield especially in cereals based rotation. As widely advocated in literature (Peoples *et al*., 1995; Kessavalou & Walters, 1999; Staggenborg *et al*., 2003; Cavigelli & Thien, 2003; Martens *et al*., 2006), legumes cultivation improve soil fertility through N_2 fixation which also reduces the following crop demand for N-fertilization. Different studies revealed marked beneficial residual effect of summer legumes (e.g., cowpea, mung bean, pigeon pea, sesbania, guar, soybean, T glycine, siratro etc.) on soil fertility and yield of the following cereal crops (Alvey *et al*., 2003; Singer *et al*., 2007). However, green manuring (e.g., Sesbania, mung bean, pigeon pea, guar and soybean etc.) not only improved yield of the following rice in rotation but reduced 50-60% N demand of the crops in rotation (Soon *et al*., 2001; Staggenborg *et al*., 2003). According to Cherr *et al*., (2006), green manuring mixed with fertilizers has increased yield of maize. The response of PP and SG on maize yield may be attributed to their N_2 fixing property and contribution in organic matter to soil. On the same soil and under the same climatic conditions, amount of N_2 fixed mainly depends on legume specie and their susceptibility to get infected with bacterial strain in the soil (Miller *et al.*, 2003). Moreover, soil N status and amount of N application at seed bed preparation also play significant role in N fixation of the legume species. Fodder and DM yields of maize were significantly greater in the plots treated with SG and PP when compared to fallow (Table 2). In response to N-fertilization, increased maize productivity as observed in the current study suggests that the preceding legume crop partly compensated N demand of the following maize crop in rotation. However, for achieving maximum yield additional N fertilization has to be supplemented in cereal based rotation system. Increased maize production observed during the current study is a function ($Y= 0.0562X - 2.236$; $R^2=0.67$) of increased plant height achieved in SG and PP treatments.

Table 1. Nutrient composition and yield of catch crops (Pigeon pea and *Sesbania gentia*) in cereal based rotation.

	Pigeon pea (PP)	*Sesbania gentia* (SG)	Difference
A. Nutrient composition			
Dry Matter (DM) %	28.27	19.93	p<0.01
Mineral Matter (% in DM)	6.49	9.53	p<0.05
Crude Protein (% in DM)	10.09	15.09	p<0.01
Crude Fiber (% in DM)	43.06	30.35	p<0.01
B. Fodder yield			
Green Fodder Yield (t ha^{-1})	26.89	33.22	p<0.05
Dry Matter Yield (t ha^{-1})	7.67	6.56	Non significant
Plant Height (cm)	184.93	193.2	Non significant
Crude Protein Yield (kg ha^{-1})	768.89	993.78	p<0.05

Table 2. Maize fodder production with and without N fertilization in wheat-maize rotation by legumes (Pigeon pea and *Sesbania gentia*) introduction as catch crop in the system.

Treatments	Green fodder yield (t ha^{-1})			Dry matter yield (t ha^{-1})			Crude protein (% in dry matter)			Crude protein yield (kg ha^{-1})		
	- N	+ N	Mean	- N	+ N	Mean	- N	+ N	Mean	- N	+ N	Mean
Control	15.89	19.56	17.72[b]	2.94	3.75	3.34[b]	9.68	13.20	11.44[a]	287.00	495.67	391.33
Pigeon pea	14.53	22.72	18.63[ab]	2.95	4.59	3.77[ab]	9.50	11.94	10.72[b]	282.22	555.67	418.94
Sesbania gentia	18.11	25.06	21.58[a]	3.57	4.83	4.20[a]	9.42	11.86	10.64[b]	334.50	571.28	452.89
Mean	**16.23**	**23.02**		**3.19**	**4.52**		**9.51**	**12.16**		**304.09**	**549.91**	
Significance												
Treatment (T)	p<0.05			p<0.05			p<0.05			NS		
N-fertilization (N)	p<0.0001			p<0.0001			p<0.0001			p<0.0001		
T x N	NS			NS			NS			NS		

Means followed by different superscripts in the same column are different (p<0.05)

Mean CP in maize fodder increased from 9.51 to 12.16% in DM in response to N fertilization ($p<0.001$). The CP contents in response to N fertilization was comparatively less efficient of legumes treatments as compared to fallow field (26 Vs 36%). The low CP contents in treated plots as compared to the control might be due to dilution effect. During the linear growth phase of development, increase in DM due to N fertilization and/or legume manuring enhanced stem fraction relatively higher than leaves which widens the leaf stem ratio. Stem contents on the other hand has three times lower nitrogen content than leaves (Akmal, 1997). Protein in forages is considered important nutrient and play pivotal role in maintaining efficiency of rumen fermentation (Owens *et al*., 2009). Fodder produced under the cereal based rotation is relatively poor (<10%) in CP contents which is usually considered as sub-optimum for ruminant animals. Nonetheless, fodder from PP and SG as catch crop when mixed with cereals will improve CP contents of the fodder for livestock. The present study suggests that a short duration legume i.e., SG and PP as catch crop for fodder can fit in a wheat-maize rotation without disturbing the existing cropping system. The N fertilization to maize, improved both yield and CP contents irrespectively, however, legume as catch crop improved yield which may contribute in reducing soil erosion which is commonly observed due to monsoon rains.

Catch crop for fodder or manure: The effect of PP and SG as fodder or green manure on subsequent maize production revealed that the effect of both legumes was similar for green fodder, DM and CP contents, however, SG resulted in higher ($p<0.05$) CP yield (Table 3). On the other hand, catch crop as green manure enhanced green fodder and DM yields of subsequent cereals in rotation. These findings suggest that soil mixing was more effective in increasing maize fodder yield presumably through supply of organic matter and more N that was available from manuring plant material in the soil. Woody stem of PP and SG is assumed to take longer time in decomposition and the beneficial effect of manuring might be more pronounced on the crops in the following seasons. It is known that more than 60% of the legume nitrogen is found in top soil layers (10-20 cm depth) for about 14 months after the green manuring (Stopes *et al*., 1996).

Table 3. Harvesting (H) and/or soil mixing (SM) effect of legumes introduction as catch crop in cereals rotation on yield and crude protein contents of subsequent fodder maize crop.

Treatments	Green fodder yield ($t\ ha^{-1}$)			Dry matter yield ($t\ ha^{-1}$)			Crude protein (% in dry matter)			Crude protein yield ($kg\ ha^{-1}$)		
	H	SM	Mean	H	SM	Mean	H	SM	Mean	H	SM	Mean
Pigeon pea	18.19	19.05	18.63	3.58	3.96	3.77	10.50	10.93	10.71	385.67	452.22	418.94
Sesbania gentia	18.89	24.28	21.58	3.73	4.67	4.20	10.91	10.37	10.64	416.94	488.83	452.89
Mean	18.54	21.67		3.65	4.32		10.71	10.65		401.31	470.53	
Significance												
Legumes	Not significant			Not significant			Not significant			P<0.05		
H-SM	p<0.05			p<0.05			Not significant			P=0.06		
Legumes xH-SM	Not significant			Not significant			p<0.05			Not significant		

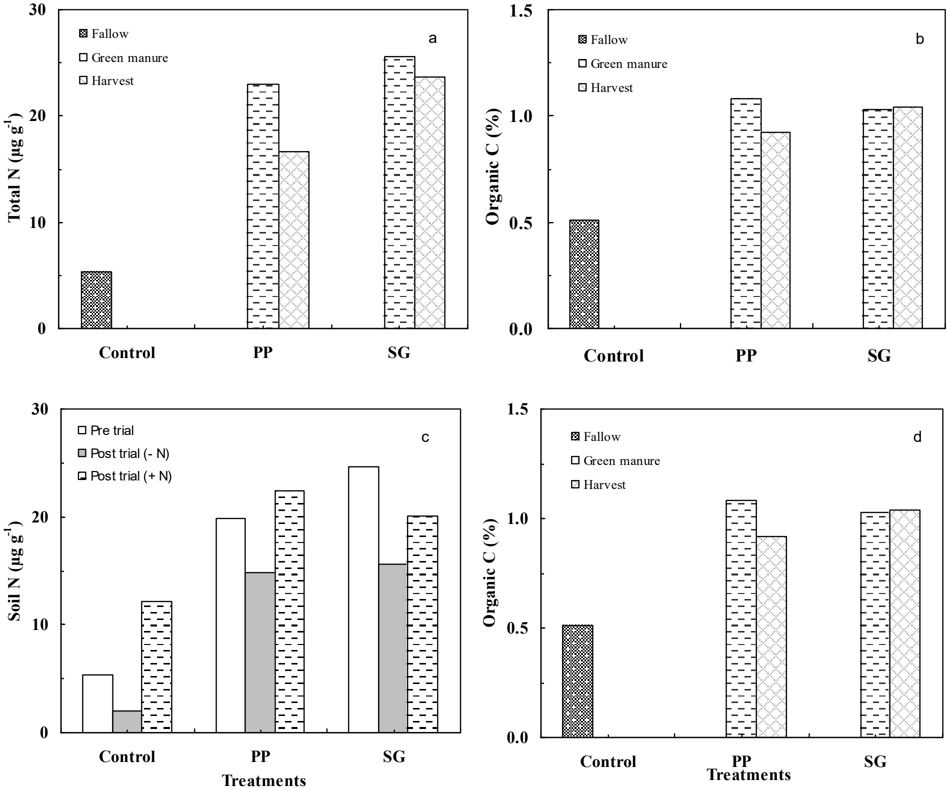

Fig. 1. Soil total N and organic carbon before (a & b) and after (c & d) manuring, respectively with and without N applications for the following fodder maize crop in a cereal based rotation. (Fallow land (control), pigeon pea (PP) and *Sesbania gentia* (SG)).

Effect of legumes residue on soil fertility: Data regarding total nitrogen and organic carbon estimated in soil is presented in Fig. 1. It was observed that differences between soil N for catch crop as green manure and/or harvested for fodder were non-significant ($p<0.05$). However, the N content in soil increased significantly ($p<0.001$) when compared with the fallow (Fig. 1a). The organic carbon in soil also showed similar trend as was noted for Soil N (Fig. 1b). Treatments PP and SG did not show any remarkable difference. The addition of N as a fertilizer in both treated plots (used as organic matter and/or fodder) enhanced N content in soil compared to control (Fig. 1c). It appears that the available N in soil was partly consumed by maize crop. Nonetheless, added mineral N to soil increased N content considerably ($p<0.001$). The soil organic C, on the other hand, showed a different trend (Fig. 1d). Added N and/or legumes (PP & SG) as catch crop did not affect soil organic matters. However, a significant reduction in soil organic C after maize harvest was observed. An improvement in soil N and organic C with legumes incorporation has been previously reported (Sommerfeldt *et al.*, 1988). In cereal based rotation, the incorporation of legumes as green manure not only improved soil N and organic C but also increased water holding capacity for the following crop which contributed to higher yield return (Hudson, 1994). We observed a positive response of both legumes when used as catch crop in the cereals rotation under the condition of the present study.

Conclusion

The study suggests that legume as green manure or fodder in a cereal based rotation is beneficial. Legume as catch crop besides improving soil N and organic C also contribute as green fodder at the time when it is acute short in the area. A significant effect on subsequent crop in terms of dry matter is an added advantage. We also noticed that the catch crop canopy protect soil from monsoon rains which has reduced top soil erosion and water run off from the filed. The findings has favourable implications for enhancing fodder supply to existing underfed livestock in the present circumstances where due to limited cultivable land a small fraction is spared for fodder cultivation.

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