Effect of Leguminous winter cover crops on soil fertility and yield of summer maize

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Abstract
A field experiment was conducted at IAAS agronomy farm, Rampur, Chitwan, Nepal from Nov. 2012 to Aug. 2013 to improve soil fertility and production of maize through the inclusion of leguminous winter cover crops in the cropping system. The experiment was conducted for two seasons in single factor randomized complete block design (RCBD) with eight treatments and three replications. Five N fixing legume crops: chickpea (*Cicer arietinum*), garden pea (*Pisum sativum* var. *sativum*), field pea (*Pisum sativum* var. *arvense*), lentil (*Lens culinaris*) and grass pea (*Lathyrus sativus*); one N fixing legume fodder: Berseem (*Trifolium alexandrinum*); one non-fixing legume: rajma bean (*Phaseolus vulgaris*); and maize (as a control) were cultivated in the first season and on the following season maize was cultivated in all plots after incorporating former crop residues. Rajma bean covered the highest area at an early stage but field pea and grass pea covered the maximum land area at a later stage. The highest dry matter production (2.32 t/ha) and nitrogen content in residues (2.57%) were obtained from lentil. Cultivation of leguminous winter cover crops had no significant effect on soil parameters. However, the incorporation of legume residues had significant effects on organic matter content, total nitrogen and available phosphorus in soils. The highest soil organic matter (3.03%) and total nitrogen (0.15%) was observed from field pea plots while the highest available phosphorus (36.00 kg/ha) was from berseem plots. Legumes cultivation and their residues incorporation into the soil had significant effects on grain, straw and dry matter yields of succeeding maize crop. Grain (3.92 t/ha), straw (5.39 t/ha) and dry matter (9.31 t/ha) yields were the highest from lentil plots while the lowest grain (2.51 t/ha), straw (3.96 t/ha) and dry matter (6.48 t/ha) from control plots. Total nitrogen uptake by maize was significant and it was the highest (141.90 kg/ha) from lentil plots and the lowest (109.80 kg/ha) from control plots. Cultivation of lentil in the winter produced satisfactory land coverage and incorporation of its residues into the soil was the best for improving soil fertility and succeeding maize yield under the Chitwan condition of Nepal.

Keywords: Biological nitrogen fixation, cover crops, legumes, soil fertility

Introduction

Cover crops can be defined as any crop grown to provide soil cover before or in between main crops. They can be annual, biennial, or perennial plant (Sullivan, 2003). Cover crops improve the productivity of soils by increasing the amount of organic matter added to the soil due to the increased biomass on the site (Hartwig and Ammon, 2002; Bruce *et al*., 1991). Cover crop, if it is a legume, can also add significant quantities of N to the soil through N sequestration (Seo *et al*., 2006). In Nepal, the cover crop is not so common in the cropping system. Lentil, chickpea, field pea, garden pea, grass pea and rajma bean are major leguminous pulse crops grown in Nepal during the winter season. Some leguminous fodder crops and vegetables are also grown during this season. The area, production and productivity of the grain legumes in the year 2012/2013 were 333436 ha, 356743 tons and 1.07 t/ha respectively (AICC, 2014). Maize ranks second most important staple food crop both in terms of area and production in Nepal. In the year 2012/13 area, production and productivity of maize was 849635 ha, 1999010 tons and 2.35 t/ha respectively (AICC, 2014). The major portion of the crop is grown in hills during the summer season and is one of the important food security crops in the Mid hills of Nepal. Sorghum, millet, cowpea and some vegetable crops are grown during autumn, however, the land remains fallow during winter. At the end of winter fallow, maize is sown in the field. As fertilizer is not timely available and costlier in Nepal, N is the limiting nutrient and its deficiency is the major constraint for the successful production of maize. If that fallow period can be utilized to grow N sparing, N fixing and N immobilizing cover crops, those will supply N to the succeeding maize crop and helps to minimize soil erosion. Thus, this experiment was conducted in the winter and following summer season of 2012/13 to improve soil fertility and production of maize through the inclusion of leguminous winter cover crops in the cropping system.

Methodology

The experiment was conducted at IAAS agronomy farm, Rampur, Chitwan, Nepal during 2012/13. The experiment was conducted for two seasons in a single factor RCBD with eight treatments and three replications. Treatments comprised of five N fixing legume pulse crops (chickpea, garden pea, field pea, lentil and grass pea), one N fixing legume fodder (Berseem), one non-fixing legume (rajma bean) and maize crop as a control. Each plot was 2.5m wide and 4m long with a net plot area of 10 square meters while the distance between the replications was 1m and within the plots was 0.5m. Leguminous cover crops were grown as the treatments in the first season (Nov. 2012 to Mar. 2013) and maize was grown on the same plots after the incorporation of legume residues in the second season (May. 2013 to Aug. 2013). The soil of the experimental site was sandy loam with a bulk density of 1.24 gm/cm^3, moderately acidic (pH 5.65), medium in soil organic matter (SOM) content (2.73%), total nitrogen (0.13%) and available potassium (155.90 kg/ha) while low in available phosphorus (21.60 kg/ha). Total rainfall during the legume period (Nov. to Mar.) was 39 mm and the average monthly temperature was 13.40 to 21.10 ˚C, while during the maize period (May to Aug.) rainfall was 1655 mm and temperature 28.50 to 30.90 ˚C. Land preparation for cover crops was done with conventional tillage and sowing on 6^{th} December 2012. 20:60:40 N: P_2O_5:K_2O kg/ha was applied at basal through urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) and single light irrigation were done at 30 days after sowing (DAS) while twice manual weeding, one at 30 and next at 60 DAS. In this season the ground coverage of cover crops was measured at 30, 60 and 90 DAS with the use of square quadrants and scales. At harvest, their fresh and dry biomass was recorded and nitrogen content in the dry biomass was analyzed.

In the second season, the land preparation was restricted only to strips (rows of the crop) with the spade and the incorporation of legume residues in those rows. Sowing was done on 8^{th} May 2013. Fertilizer was applied at the rate of 90:60:40 N: P_2O_5:K_2O kg/ha. Half N, full P and K were applied at basal and ½ N at 25 DAS. Rainfall was sufficient for the crop while manual weeding at 25 and 50 DAS was done. Grain, straw and dry matter yield of maize was recorded at harvest. Grain and plant samples were analysed for nutrient uptake. Soil samples were collected at legume harvest and maize harvest from each plot and analysed for pH, SOM content, total nitrogen, available phosphorus and available potassium. Methods of soil and plant analysis are tabulated in the table below.

Table 1. Methods of laboratory analysis for soils and plants

Parameters	Analysis methods
Soil pH	Beckman Glass Electrode pH meter (Wright, 1939)
Soil texture	Hydrometer (Klute, 1986)
Soil organic matter	Walkley and Black (1934)
Soil total nitrogen	Kjeldahl distillation (Bremner and Mulvaney, 1982)
Soil available phosphorus	Olsen’s bicarbonate (Olsen *et al.,* 1954)
Soil available Potassium	Ammonium acetate (Black, 1965)
Plant total nitrogen content	Kjeldahl distillation (Bremner, 1982)
Plant phosphorus content	Vandomolybdo-Phosphoric yellow color method (Jackson,1967)
Plant potassium content	Flame photometer (Black, 1965)

Results and Discussions

Land coverage of winter legumes

Winter legumes showed a significant variation in land coverage. Rajma bean covered the maximum land area (22.99%) at 30 DAS which was similar to lentil (21.33%) and significantly higher than other legumes. Field pea covered a significantly higher area (43.53%) at 60 DAS and was similar to lentil, grass pea and rajma bean while it was higher than other legumes. Similarly, field pea covered the maximum land area (66.53%) at 90 DAS which was at par with grass pea (64.93%) but higher than other legumes. Land coverage by winter legumes started increasing from early stage to maturity but the rate of increment was higher on field pea and grass pea (Figure 1) than others. Creamer *et al*. (1997) also found that 13 cover crops and mixtures (mainly legumes) achieved 30% ground cover one month after planting, and generally 100% cover within three months in irrigated field condition. Tanaka *et al*. (1997) found that field pea (*Pisum sativum*) provided adequate surface cover to control soil erosion effectively in a four-year rotation of wheat-fallow.

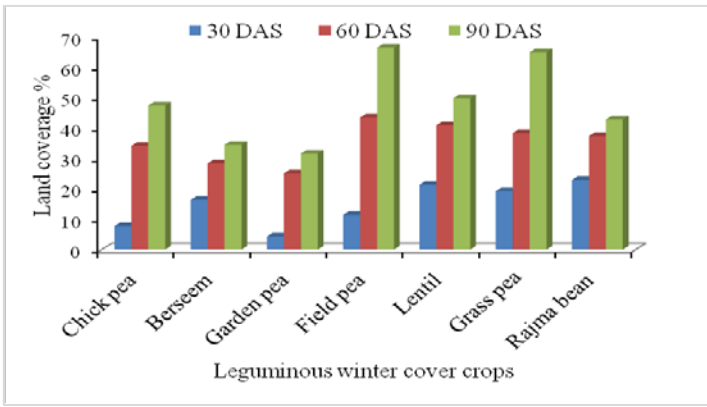

Fig. 1: Land coverage by winter leguminous cover crops at Rampur, Chitwan, Nepal, 2012/13

Table 2. Yields of fresh and dry biomass and Nitrogen content in the residues of leguminous winter cover crops at Rampur, Chitwan, Nepal, 2012/13

Cover crops	Yield of biomass (t/ha)		Residue N (%)
	Fresh	Dry	
Chick pea (*Cicer arietinum*)	5.93[a]	1.99[bc]	2.26[bc]
Berseem (*Trifolium alexandrinum*)	5.08[ab]	1.28[d]	1.82[d]
Garden pea (*Pisum sativum* var. *sativum*)	3.57[bc]	1.81[c]	2.19[c]
Field pea (*Pisum sativum* var. *arvense*)	2.74[c]	2.22[ab]	2.46[ab]
Lentil (*Lens culinaris*)	3.61[bc]	2.32[a]	2.57[a]
Grass pea (*Lathyrus sativus*)	3.93[bc]	2.21[ab]	2.30[bc]
Rajma bean (*Phaseolus vulgaris*)	5.81[a]	1.39[d]	1.48[e]
LSD (P<0.05)	1.77	0.23	0.19
Sem ±	0.57	0.07	0.06
CV%	22.69	7.02	5.17

Note: *Means followed by the same letter(s) in a column are not significant at 5% level of significance as determined by Duncan's multiple range test*

Among these winter legumes, chickpea yielded the maximum fresh biomass (5.93 t/ha) which was at par with berseem and rajma bean but higher than other legumes. Field pea produced the lowest fresh biomass (2.74 t/ha) at the time of harvest. In contrast to this, the dry matter production was maximum (2.32 t/ha) on lentil which was similar to field pea and grass pea but significantly higher than other legumes (Table 2). Berseem produced the lowest dry matter (1.28 t/ha) yield. Nitrogen percentage was the highest on the lentil residue (2.57%) while rajma bean residue had the lowest nitrogen content (1.48%). Legumes greatly varied on fresh and dry biomass production. This finding was in accordance with (Sharma and Mitra, 1988), (Beri *et al*.,1989) and (Ngome *et al*.,2011).

Effects of winter legumes on soil parameters

Legumes didn't show a significant change in SOM content at legumes harvest. After the incorporation of the legume residues, the SOM content of soil on all legumes increased except rajma bean, while it was decreased on control plots. The effect of field pea residue on SOM content was significantly higher (3.03%) than the rajma bean and the control while at par with other legume residues (Table 3). A similar finding was revealed by Yan and Li (1985) that incorporation of legumes into soil increased organic matter content by 0.11%. Similarly, Shashidhara (1986) also reported an increase in organic carbon content in the soil, from 0.49% and 0.51% due to green manuring of cowpea and horse gram, respectively over the initial status of 0.47% and 0.48 %. Total soil nitrogen among treatments was not significant at the harvest of legume (before the incorporation of legume residues). Legume residues significantly affected the total nitrogen contents of soil after the harvest of maize (Table 3). Total nitrogen was the highest (0.15%) on the field pea and lentil plot which were similar to other legumes except for rajma bean. Nitrogen content in rajma bean plots (0.13%) was similar to the garden pea, berseem and grass pea plots but it was significantly higher than control plots (0.12%).

Misra and Misra (1975) also revealed that legumes as green manure crop taken either in rotation or mixture apart from adding organic matter to the soil increased soil N due to symbiotic N fixation of atmospheric N. Yan and Li (1985) also reported that incorporation of legumes into soil increased total soil N by 16.10% and found available nitrogen higher in green manured plots by 14.10% than control. A similar finding was also obtained by Shashidhara (1986) that available nitrogen has increased to 222.00 kg/ha and 220.00 kg/ha over the initial status of 202.00 kg/ha and 198.00 kg/ha by green manuring of cowpea and horse gram respectively. Available phosphorus in soil showed the trend different as compared to SOM and total nitrogen content before and after the incorporation of legume residue. Chickpea, berseem, garden pea, field pea and lentil increased the available phosphorus in the soil after the incorporation of residues into the soil. But grass pea and rajma bean decreased the available phosphorus slightly while on the control plot it remained unaffected.

Available phosphorus in the soil before the incorporation of legume residues was similar in all treatments. After the incorporation of legume residue, plant-available phosphorus in soil was significant. Berseem plot produced the highest available phosphorus (36.00 kg/ha) which was similar to other legumes but higher than the control plot. Available phosphorus on the control plot (26.60 kg/ha) was the minimum and at par with all legumes except berseem. Yan and Li (1985) reported that the incorporation of legumes into soil increased available phosphorus by 10.50 to 24.60 % over the control. Available soil potassium and soil pH were not affected by the residue incorporation.

Table 3. Effects of winter legumes on soil parameters before and after legume residues incorporation at Rampur, Chitwan, Nepal, 2012/13

Treatment	Organic matter %		Total nitrogen %		Available P_2O_5 kg/ha		Available K_2O kg/ha		Soil pH	
	before	after	before	after	before	after	before	after	before	After
Chick pea (*Cicer arietinum*)	2.77	3.00[a]	0.14	0.15[a]	28.90	35.60[ab]	158.60	143.50	5.60	5.50
Berseem (*Trifolium alexandrinum*)	2.78	2.85[ab]	0.14	0.14[ab]	33.30	36.00[a]	147.80	131.40	5.40	5.40
Garden pea (*Pisum sativum* var. *sativum*)	2.76	3.01[a]	0.14	0.14[ab]	33.30	35.10[ab]	158.30	127.00	5.60	5.40
Field pea (*Pisum sativum* var. *arvense*)	2.81	3.03[a]	0.14	0.15[a]	31.00	33.00[ab]	153.90	138.50	5.50	5.30
Lentil (*Lens culinaris*)	2.74	2.98[a]	0.13	0.15[a]	26.50	28.10[ab]	156.90	146.10	5.40	5.40
Grass pea (*Lathyrus sativus*)	2.79	2.97[a]	0.14	0.15[ab]	30.00	29.30[ab]	157.80	141.20	5.60	5.30
Rajma bean (*Phaseolus vulgaris*)	2.69	2.69[bc]	0.13	0.13[bc]	28.50	28.40[ab]	160.80	147.80	5.40	5.40
Control	2.63	2.55[c]	0.13	0.12[c]	26.60	26.60[b]	156.30	136.60	5.70	5.30
LSD (P<0.05)	ns	0.24	ns	0.02	ns	8.13	ns	ns	ns	ns
SEm±	0.04	0.07	0.03	0.05	2.10	2.68	6.68	11.99	0.07	0.08
CV%	2.64	4.83	3.16	6.45	12.26	14.75	7.41	14.95	2.43	2.72

Note: *Means followed by the same letter(s) in a column are not significant at 5% level of significance as determined by the Duncan's multiple range test*

Effects of leguminous winter cover crops on summer maize

Legumes cultivation and their residues incorporation had a significant effect on grain, straw and dry matter yields of succeeding maize crop (Table 4). Grain (3.92 t/ha), straw (5.39 t/ha) and dry matter (9.31 t/ha) yields were the highest on lentil plots while the lowest on control plots. A similar finding was also reported by Sogbedji *et al*., (2006) that the use of mucuna (*Mucuna pruriens* L.) and pigeon pea (*Cajanus cajan* L.) as cover crops increased maize grain yield by 37.50% and 32.10 %, respectively in the following year. Ngome *et al*., (2011) also found that maize yield increased by 0.50-2.00 t/ha on *Mucuna pruriens* and 0.50-3.00 t/ha on *Arachis pintoi* cultivated lands of three different soil types in Kenya.

Table 4. Effects of leguminous winter cover crops on grain, dry matter and straw yields of maize at Rampur, Chitwan, Nepal, 2012/13

Treatments	Yield (t/ha)		
	Grain	Dry matter	Straw
Chick pea (*Cicer arietinum*)	3.38[ab]	8.10[ab]	4.72[a]
Berseem (*Trifolium alexandrinum*)	3.33[ab]	8.66[ab]	5.33[a]
Garden pea (*Pisum sativum* var. *sativum*)	3.56[ab]	8.43[ab]	4.86[a]
Field pea (*Pisum sativum* var. *arvense*)	3.60[ab]	8.79[ab]	5.19[a]
Lentil (*Lens culinaris*)	3.92[a]	9.31[a]	5.39[a]
Grass pea (*Lathyrus sativus*)	3.57[ab]	8.69[ab]	5.11[a]
Rajma bean (*Phaseolus vulgaris*)	2.90[bc]	7.73[b]	4.82[a]
Control	2.51[c]	6.47[c]	3.96[b]
LSD (P<0.05)	0.72	1.17	0.72
SEm±	0.24	0.38	0.23
CV%	12.43	8.10	8.41

Note: *Means followed by the same letter(s) in a column are not significant at 5% level of significance as determined by the Duncan's multiple range test.*

Total nitrogen uptake by maize was significant and it was the highest (141.90 kg/ha) on lentil plots and the lowest (109.80 kg/ha) on control plots. While total phosphorus and potassium uptake were not affected by the legumes and their residues but the trend was similar to nitrogen uptake pattern.

Conclusions

Rajma bean covered the highest area at an early stage but later field pea covered the maximum land area while garden pea the minimum land area throughout the crop growing period. Chickpea produced the highest fresh biomass (5.93 t/ha) and field pea the lowest (2.74 t/ha) at the time of harvest. The dry matter production was the maximum (2.32 t/ha) on lentil and the minimum on Berseem (1.28 t/ha). Nitrogen content on residue was also the highest on lentil (2.57%) while the lowest on rajma bean (1.48%). Cultivation of winter legume crops had no significant effects on soil parameters. However, the incorporation of legume residues had significant effects on SOM content, total nitrogen and available phosphorus. The highest soil organic matter (3.03%) and total nitrogen (0.15%) were obtained on field pea plots while the highest available phosphorus (36.00 kg/ha) was recorded on berseem plots. Legumes cultivation and their residues incorporation had a significant effect on grain, straw and dry matter yields of succeeding maize crop.

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