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Effect of Legumes as Intercrop in Maize (*Zea mays* L.) On Soil Fertility, Maize Equivalent Yield and Nutrient Recycling

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ABSTRACT

A field experiment was conducted during the kharif season of 2005 and 2006 at Zonal Agricultural Research Station, Shimoga, on red sandy loam soil to find out the effect of different intercrops in maize on soil fertility and yield in Southern Transition Zone of Karnataka. The experiment consisted 18 treatments, involving sole crop of maize at uniform row spacing (URS) and in paired row system (PR), sole crop of different intercrops and intercropping system treatments in paired row system (45-75-45 cm) as additional series were laid out in CRBD and replicated thrice. Increase in soil pH and EC was noticed due to introduction of pulse crops in maize as intercrops. Significantly higher soil organic carbon was noticed in plots grown with sole crop of pulses. Even the intercrop treatments recorded significantly higher soil organic carbon than sole crop of maize. The highest organic carbon content was recorded in the plots under maize + field bean var. local (0.573) followed by maize + red gram. Higher available nitrogen, phosphorus and potassium were noticed in plots under sole stands of intercrops (pulses) than sole crop of maize as well. Besides, intercrop treatments too recorded significantly higher available nutrients (NPK) than sole maize. Among intercrop treatments, maize + local field bean) and maize + red gram var. BRG-1 (257.5 kg ha^{-1}) have recorded_higher available nutrients than others.

***Key words**: Maize, Intercropping, Organic Carbon, Recycling and Soil fertility*

INTRODUCTION

Maize is gaining popularity in Southern Transition Zone of Karnataka, where, the crop is cultivated during rainy season, the amount and distribution of rainfall also favours for the inclusion of short duration intercrop. The sustainability of current yields and prospects of higher yields of maize are threatened by soil compaction, low levels of organic matter, and extensive monoculture and ill distribution of rainfall all of which are of typical of this region. Continuous monocropping of maize on large tracts of the land with little or no provision for soil fertility maintenance contributed to the rapid depletion of soil nutrients in general and nitrogen in particular.

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Intercropping is one of the potential areas to achieve sustainability with respect to soil fertility and productivity of maize growing areas. Intercropping of suitable genotypes of pulses in maize not only provide nutritional security and improve the productivity but also cause for the soil improvement. It was reported that legumes favorably improve the physical, chemical and biological aspects the soil. One to two rows of soybean intercropped with maize caused for improvement in soil structure, as judged from the decrease in the bulk density, hydraulic conductivity, and available water besides increasing organic carbon content compared to pure maize cropped soils. The beneficial effects must be perhaps due to root exudates, and root and shoot residue addition and their decay[2]. Inclusion of legumes in the cropping system benefited through nitrogen fixation by legumes to cereals and improves the soil fertility. These benefits are largely due increased total biomass, amount of N fixed, amount of N added to soil through roots nodules and leaf fall (litter), increased biological activity and increased availability of nutrients other than N[10]. They also reported higher organic C, total N, available N and Olsen's P. Thus kind of intercrop/variety and spatial arrangement in intercropping have important effects on soil-fertility status. With this background, the study was undertaken to find out the effect of different intercrops on soil fertility and nutrient recycling in Southern Transition Zone of Karnataka.

MATERIAL AND METHODS

A field experiment was conducted during the *kharif* season of 2005 and 2006 at Zonal Agricultural Research Station, Shimoga,. The soil was red sandy loam (*Alfisol*) in texture having 44.8, 32.2, 12.4 and 10.6 per cent coarse sand, fine sand, silt and clay, respectively. Soil was slightly acidic (5.4), medium in organic carbon content (0.43) per cent and low in available N (260 kg ha^{-1}), very high in P (51.2 kg ha^{-1}) and medium in K (67.5 kg ha^{-1}). The experiment consisted 18 treatments, involving sole cop of maize at uniform row spacing (URS) and in paired row system (PR), sole crops of soybean (var. KHSb-2 and var. KB-79), french bean (var. Arka Komal for grain and vegetable), field bean (var. local and HA-3) and red gram (var. Hyd-3c and BRG-1). One of row of the above intercrops was introduced in between two pairs of maize under paired row system of planting (45-75-45 cm) as additional series. The treatments were laid out in CRBD and replicated thrice. Sole crops of maize (URS), soybean (var. KHSb-2 and var. KB-79), french bean (var. Arka Komal for grain and vegetable), field bean (var. local), field bean (var. HA-3) and red gram (var. Hyd-3c and BRG-1) were sown at 60, 30, 30, 45, 30 and 60 cm row spacing and 10, 10, 22.5, 15 and 30 cm of plant distance, respectively. While paired planting was done with a spacing of 45-75-45 cm x 30 cm. The recommended intra-row spacing was adopted for intercrops in intercropping treatments. The crops were sown simultaneously in second fortnight of June. A common dose of fertilizers @ 100:50:25 kg NPK per ha was applied to maize both for pure and inter crop treatment plots for maize rows. Fifty of the N and full dose of P and K were applied at the time of sowing maize as basal remaining 50 per cent was applied in two equal splits at 30 and 50 DAS. While, for intercrops respective recommended dose fertilizers were applied based on area basis and entire quantity of fertilizers for intercrops was applied at the time of sowing as basal. A total of 1409 and 789.3 mm rainfall was received during 2005 and 2006, respectively. The litter fall per ha was estimated based on litter collected from one square meter area selected from net plot area and their nutrient content was analyzed through standard procedures. Soil samples were collected after the harvest of the crop during second year from all treatment plots. The samples were analyzed for organic carbon and available N, P and K through standard procedures.

RESULTS AND DISCUSSION

Effect of different intercropping systems on maize equivalent

The data on maize equivalent yield pooled over years indicated the statistical superiority of maize + field bean var. local (5510 kg ha^{-1}) over others (Table 3). The treatments maize + red gram var. BRG-1(4981 kg ha^{-1}), sole crop of maize sown at

URS (5041 kg ha^{-1}), maize + French bean (grain) (4929 kg ha^{-1}) and sole crop of maize sown under paired row system (4784 kg ha^{-1}) were next in the order and at par with each other. Among intercrop treatments maize + field bean var. local, maize +red gram var. BRG-1 and maize + French bean (grain) found to be significantly better than other intercropping treatments This may be attributed to higher yield of field bean var. local and the market price. In contrast, despite higher market prices for sesame, Patra *et al*[5]. have obtained low maize equivalent in maize + sesame intercropping system. This may be assigned to the synergetic effect of maize and field bean in utilization natural resources. Addition of dry matter to the soil as a result of higher litter fall (leaf litter) and nitrogen fixation by pulse intercrops viz., field bean and red gram in maize were also reason for higher maize equivalent yield in these treatments. Similarly, Shivay *et al*[8]., have obtained higher maize equivalent yield with maize + urdbean/soybean intercropping systems over sole crop of maize.

Litter fall and nutrient recycling

Litter fall pooled over years revealed that the significantly higher leaf litter was noticed in sole crop of field bean var. local (2100 kg ha^{-1}) over others closely followed were sole crop of red gram var. BRG-1 (1677 kg ha^{-1}) and var. Hyd. 3C (1609 kg ha^{-1}) (Table 1). This may be attributed to the creeping and spreading nature of field bean and its simultaneous production and shedding of leaves over its long growing period. Similarly, long duration and branching habit of red gram contributed more leaf fall. The nutrient composition of different litter material is furnished in (Table 2). The nutrient content of different intercrop litter varied from 1.68 to 2.04 per of nitrogen, 0.06 to 0.11 in Phosphorus and 0.16 to 0.46 in Potassium. The higher N and P content were found in french bean and soybean litter while field bean litter was rich in potassium.

The higher quantity of nutrients recycled to the soil was found with sole crop of field bean var. local followed by sole crop of red gram var. BRG-1 and Hyd-3c, maize + field bean var. local, maize + red gram var. BRG-1 and maize + red gram var. Hyd-3c. This may be attributed to the higher quantity of litter fallen in these treatment as both field bean var. and red gram have been occupying the land for long duration (Table 1).

Changes in soil properties and fertility

The soil pH influenced by various maize based intercropping systems varied significantly among treatments (Table 3). From the perusal of the table it is noted that the higher pH was found under different intercrops sown at pure stand when compared to that of intercrop and also to sole crop of maize. Increase in soil pH was observed under different leguminous crops at the end of second year of experimentations. The highest pH of 5.67 was found in soils of sole crop of soybean which on par all other sole crop treatments of pulses and significantly higher to sole crop of maize (5.1). It was also observed that pH recorded by different intercrop was numerically higher than pH of soil under crop of maize except with maize + field bean var. HA-3.

The data on electric conductivity indicated that there was no appreciable change in EC of soil put to different intercropping systems. However, almost all intercrop treatments except maize + red gram var. BRG-1 (0.16 ds m^{-1}) recorded significantly higher EC than sole crop of maize sown at URS (Table 3)

Soil organic carbon

Significantly higher soil organic carbon was noticed in plots grown with sole crop of pulses. Even the intercrop treatments recorded significantly lower organic carbon than their respective sole crops. Among intercrop treatments, higher organic carbon content was recorded in the plots put to maize + field bean var. local (0.573) followed by maize + red gram. This may be attributed to the addition of dry matter to the soil as a result of higher litter fall (leaf litter) and nitrogen fixation in pure stand of pulses and also introduction of these as intercrops in maize. Significant amount of litter fall (Up to 2100 kg per ha) observed in plot put to pulse crop compared to no litter fall under maize sole cropping (Table 1) justify the changes in organic carbon status. The results are in line with findings of Wikson Makumbe *et al*. that maize + glyricidia intercropping system could sequester more C than sole maize (Table 3).

Further, Wani *et al*[11] reported 67 per cent in 22 years) higher carbon content of top 15 cm soil layer in case of pigeonpea based intercropping system as compared to non legume system. Paustian *et al*[6]., recorded higher soil carbon input with the continuous cropping, particularly when fertilizers were applied and legumes were included in the system. Traditionally, farmers have been applying organic manure such as FYM and leaf litter to sustain their maize production and maintaining soil fertility[9].

Available nutrient status

The available, N, P and K in soil after the harvest of crops varied with the kind of intercrops. In this investigation, significant differences were found among the various treatments, with regard to available soil nutrient status (nitrogen, phosphorous and potassium) at the end of experimentation. Intercropping was reported to significantly increase the available N content and reduce both available P and K content compared to initial and post available N, P and K content when fertilizers applied only to main crop of maize[4].

The data showed that the higher available nitrogen was noticed in plots under sole crops stands of pulses than sole crop of maize as well as respective intercrop treatments. The highest available nitrogen was recorded by sole crop of field bean var. local (281.4 kg ha^{-1}) which was significantly superior to all except with sole crop of red gram var. BRG-1 (274.3 kg ha^{-1}) and maize + field bean var. local (263.3 kg ha^{-1}). Almost intercrop treatments recorded significantly higher available nitrogen than their respective sole crop. Among intercrop treatments, maize + local field bean (263.3 kg ha^{-1}) and maize + red gram var. BRG-1 (257.5 kg ha^{-1}) have recorded higher available N (Table 3). This may be due to nitrogen fixation by root nodules and mineralization of N from organic matter accumulation due to litter fall. Also might be due to residual effect of added fertilizer nutrients to respective crops as per recommendation based on population in intercropping systems. More respiration and more microbial activity resulted in more net mineralization under intercropped situation compared to sole stand[7] and reduced nitrate leaching in intercropping system treatments. Significant increase in available soil nitrogen also obtained by Padhi and Panigrahi[4] in their study on maize based intercropping systems in all intercropping systems and irrespective of row ratios compared to initial and post-harvest available soil N content than sole maize. Similarly, Ngo Huu Tinh[3], have obtained higher humus content and total nitrogen and improvement in soil fertility following intercropping in maize compared to sole crop of maize.

The available soil P recorded under sole crop of intercrops was higher than under respective maize based intercropping systems. Significantly higher available soil phosphorus than others was noticed with plot under sole crop of field bean var. local (63.1 kg ha^{-1}) closely followed by sole crop of red gram var.Hyd-3c (60 kg ha^{-1}) which were on par with each other (Table 3). This may be attributed to phosphorus build up as a result of P addition to the soil as per population basis to respective crops in the intercropping systems and litter fall and also due to P build up as a result of added fertilizers. The mineralization of native P in soil due to root exudates and organic acids released during decomposing of organic matter in legume cropping systems could also be the reason for higher available P noticed. Inal, *et al*[1]. reported significantly higher acid phosphatase activity in rhizosphere of intercropped maize than sole cropping with maize.

It was observed that the sole crop of field bean var. local (321.3 kg ha^{-1}), maize + field bean var. local (276.8 kg ha^{-1}), french bean (grain) (270.5 kg ha^{-1}) have recorded significantly higher available soil K than sole crop of maize (247.9 kg ha). Except with red gram the available soil potassium recorded under different sole stand of intercrops was higher than their respective crops (Table 3). Increased biological and chemical activity in rhizosphere might have resulted in higher available nutrients under sole crop of pulses and intercropping systems[1].

The highest soil organic carbon content was recorded in the plots put to maize + field bean var. local followed by maize + red gram.

All intercropping treatments recorded higher available nutrients than sole crop of maize, highest being noticed in plot grown with maize + field bean (local) and maize + red gram. Thus, intercropping in maize with field bean, red gram and other pulses helps in improving soil fertility as compared to sole crop of maize.

Table 1: Amount of litter produced and nutrients recycled as a result of litter fall as influenced by different intercropping systems (Pooled data of 2005 and 2006)

Treatments	Litter fall	Nutrients added		
		N	P	K
	(kg ha^{-1})			
T_1 Sole maize at URS* of 60 cm	1.05* (0)	1.0 (0)	1.0 (0)	1.0 (0)
T_2 Sole maize at PR of 45-75-45 cm	1.08 (0)	1.0 (0)	1.0 (0)	1.0 (0)
T_3 Sole soybean (Vr. KHSb 2)	16.9 (286.3)	2.54 (5.47)	1.17 (0.26)	1.46 (1.14)
T_4 Sole soybean (Vr. KB- 79)	15.4 (239.5)	2.39 (4.73)	1.09 (0.22)	1.37 (0.88)
T_5 Sole red gram (Vr. Hyd- 3c)	40.1(1609)	5.29 (27.03)	1.43 (1.03)	2.51(5.31)
T_6 Sole red gram (BRG -1)	42.0 (1677)	5.56 (30.2)	1.43 (0.97)	2.71 (6.36)
T_7 Sole field bean (Var.- HA_3)	18.5 (343.8)	2.72 (6.4)	1.13 (0.29)	1.43 (1.10)
T_8 Sole field bean (Local Avare)	45.5 (2100)	6.33 (39.5)	1.76 (1.41)	3.25 (9.66)
T_9 French bean (Var. Arka Komal) Vegetable	17.0 (293)	6.62 (5.98)	1.17(0.38)	1.35 (0.82)
T_{10} French bean (Var. Arka Komal) Grain	16.1 (263)	2.51 (5.37)	1.13 (0.29)	1.32 (0.74)
T_{12} Maize (PR*) + Soybean var. KHSb-2	12.6 (160)	3.01 (13.05)	1.07 (0.14)	1.28 (0.64)
T_{13} Maize (PR) + Soybean var. KB- 79	12.3 (150)	1.98 (2.92)	1.06 (0.12)	1.25 (0.55)
T_{14} Maize (PR) + Red gram var. Hyd - 3c	33.0 (1092)	4.39 (18.32)	1.31 (0.71)	2.14 (3.60)
T_{15} Maize (PR) + Red gram var. BRG-1	31.5 (995)	4.21 (16.81)	1.26 (0.60)	2.14 (3.60)
T_{16} Maize (PR) + Field bean var. HA- 3	12.7 (162)	2.00 (3.02)	1.06 (0.13)	1.22 (0.48)
T_{17} Maize (PR) + Field bean var. Local	36.8 (1366)	5.14 (25.7)	1.54 (1.37)	2.69 (6.28)
T_{18} Maize (PR) + French bean var. Arka Komal V)	13.7 (191)	2.2 (3.89)	1.10 (0.21)	1.24 (0.53)
T_{19} Maize (PR) + French bean var. Arka Komal (G)	11.7 (139)	1.95 (2.84)	1.07 (0.15)	1.21 (0.48)
S. Em ±	0.98	0.13	0.22	0.55
C.D. (P=0.05%)	2.72	0.36	0.062	0.152

URS* = Uniform Row Spacing PR* = Paired Row System
* = Transformed values ⁄(x+1), Original values are in parenthesis

Table 2: Nutrient content of litter material of different intercrops

Litter material	N (%)	P (%)	K (%)
Field bean var. local	1.88	0.10	0.46
Field bean var. HA-3	1.86	0.08	0.16
Soybean var. KHSb-2	1.91	0.085	0.40
Soybean var. KB-79	1.93	0.08	0.37
Red gram var. Hyd-3c	1.68	0.065	0.33
Red gram var. BRG-1	1.69	0.06	0.36
French bean var. Arka Komal	2.04	0.11	0.28

Table 3: Effect of different maize based intercropping systems on soil properties at the end of experimentation (after two years)

Treatments	pH	EC	Organic carbon (%)	Available Nutrients(kg ha^{-1})			Maize equivalent yield (kg ha^{-1})*
				N	P_2O_5	K_2O	
T_1 Sole maize at URS* of 60 cm	5.10*	0.014	0.400	220.0	47.7	247.9	5041
T_2 Sole maize at PR* of 45-75-45 cm	5.07	0.016	0.390	214.4	46.3	236.9	4784
T_3 Sole soybean (Vr. KHSb 2)	5.67	0.020	0.507	259.3	54.8	257.7	2009
T_4 Sole soybean (Vr. KB- 79)	5.53	0.019	0.467	261.4	52.7	261.5	2139
T_5 Sole red gram (Vr. Hyd- 3c)	4.60	0.019	0.510	250.3	60.0	258.9	3172
T_6 Sole red gram (BRG -1)	5.33	0.011	0.543	274.3	57.0	224.8	3865
T_7 Sole field bean (Var.- HA_3)	5.37	0.016	0.433	244.3	56.1	248.4	1538
T_8 Sole field bean (Local Avare)	5.40	0.017	0.537	281.4	63.1	321.3	2932
T_9 French bean (Var. Arka Komal) Vegetable	5.60	0.016	0.467	238.4	50.4	261.6	1562
T_{10} French bean (Var. Arka Komal) Grain	5.60	0.017	0.450	242.9	52.5	270.5	1820
T_{12} Maize (PR) + Soybean var. KHSb-2	5.37	0.027	0.523	233.1	52.6	238.7	4434
T_{13} Maize (PR) + Soybean var. KB- 79	5.10	0.024	0.520	235.9	49.6	259.4	4261
T_{14} Maize (PR) + Red gram var. Hyd - 3c	5.17	0.018	0.523	240.8	56.7	258.8	4581
T_{15} Maize (PR) + Red gram var. BRG-1	5.23	0.016	0.533	257.5	59.0	266.7	4981
T_{16} Maize (PR) + Field bean var. HA- 3	4.90	0.024	0.450	241.0	52.0	217.9	4210
T_{17} Maize (PR) + Field bean var. Local	5.33	0.023	0.573	263.3	56.0	276.8	5510
T_{18} Maize (PR) + French bean var. Arka Komal V)	5.13	0.023	0.453	237.4	48.3	255.9	4524
T_{19} Maize (PR) + French bean var. Arka Komal (G)	5.33	0.021	0.463	237.5	54.4	237.5	4929
S. Em ±	0.14	0.0013	0.015	5.07	1.18	8.00	104
C.D. (P=0.05%)	0.38	0.0036	0.051	14.1	3.28	22.2	287.6

URS*= Uniform Row Spacing PR*= Paired Row System * Pooled data of 2005 and 2006

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