Karnataka J. Agric. Sci., 28(2): (147-150) 2015

Studies on changes in soil fertility, maize equivalent yield and nutrient recycling in different maize (*Zea mays* L.) based intercropping systems

G. K. GIRIJESH, A. S. KUMARA SWAMY AND S. P. NATARAJU

Department of Agronomy, College of Agriculture, Shivamogga
University of Agricultural and Horticultural Sciences, Shivamogga - 577 204, Karnataka, India
E-mail: gk.girijesh@gmail.com

(Recevied: August, 2013 ; Accepted: April, 2015)

Abstract: Field experiments were conducted for two consecutive *kharif* seasons to find out the effect of different intercrops with maize on soil fertility and nutrient recycling in maize. The experiment consisted of 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. Increase in soil pH and EC was noticed due to introduction of pulses in maize as intercrops. Significantly higher soil organic carbon was observed 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 with maize + field bean var. local (0.573) followed by maize + red gram. Litter fall due to introduction of pulses justify the changes in organic carbon status. Higher available nitrogen was observed in plots with sole stands of intercrops (pulses) as compared to sole crop of maize as well as respective intercrop treatments. Intercrop treatments were also recorded significantly higher available nitrogen than sole maize. Among the intercrop treatments, maize + local field bean (263.3 kg ha^{-1}) and maize + red gram var. BRG-1 (257.5 kg ha^{-1}) recorded higher available N. The available soil P recorded with sole crop of intercrops was higher than that under respective maize based intercropping systems. Further, plots under intercrop treatments also registered higher available P than sole maize plot. 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}) recorded significantly higher available soil K than sole crop of maize (247.9 kg ha).

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

Introduction

Maize is gaining popularity in Southern Transition Zone of Karnataka, where, the crop is cultivated during *kharif* season, the amount and distribution of rainfall also favour 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, extensive monoculture and erratic distribution of rainfall which are the typical features 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. 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 with maize not only provide nutritional security and improve the productivity but also result in soil improvement. It has been well documented that legumes favorably improve the physical, chemical and biological aspects of the soil. One or two rows of soybean intercropped with maize caused 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, root and shoot residue addition and their decay. Inclusion of legumes in the cropping system benefits through nitrogen fixation by them and improves the soil fertility. These benefits are largely due to increased total biomass production, amount of N fixed, amount of N added to soil through root nodules and leaf fall (litter), increased biological activity and increased availability of nutrients other than N (Wani and Lee, 1995). They also reported higher organic C, total N, available N and Olsen's P. Thus, pulse based cropping systems and spatial arrangement of intercrops have an important effects on soil-fertility status. With this background, the present study was undertaken to find out the effect of different intercrops with maize on soil fertility and nutrient recycling in Southern Transition Zone of Karnataka.

Material and methods

Field experiments were conducted for two consecutive *kharif* seasons at the Zonal Agricultural Research Station, Shivamogga. 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 pH), medium in organic carbon content (0.43%) 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 comprised of 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 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 crop 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 inter row spacing and 10, 10, 22.5, 15 and 30 cm intra row spacing, 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 during second fortnight of June. A common dose of fertilizers @ 100:50:25 kg NPK per ha was applied to maize both for sole and intercrop treatment plots for maize rows. Fifty per cent of the N and full dose of P and K were applied at the time of maize sowing as basal dose, remaining 50 per cent was applied in two equal splits at 30 and 50 days after sowing. While, for intercrops, respective recommended dose of fertilizers were applied based on area 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 first and second year of experimentation, 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

The pooled data over two years revealed that the significantly higher leaf litter was observed with sole crop of field bean var. local (2100 kg ha^{-1}) over others closely followed by sole crop of red gram var. BRG-1 (1677 kg ha^{-1}) and var. Hyd. 3c (1609 kg ha^{-1}) on dry wight basis (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 to more leaf fall. The nutrient content of different intercrop litter varied from 1.68 to 2.04 per cent of nitrogen, 0.06 to 0.11 per cent phosphorus and 0.16 to 0.46 per cent potassium. The higher N and P content were found in french bean and soybean litter while field bean litter was rich in potassium (Table 2). The higher quantity of nutrients recycled to the soil was found with sole crop of field bean var. local (39.5. 1.41 and 9.66 kg NPK per ha^{-1}) followed by sole crop of red gram var. BRG-1 (30.2, 0.97 and 6.36 kg NPK per ha^{-1}) and Hyd-3c (27.03, 1.03 and 5.31 kg NPK ha^{-1}, respectively), maize + field bean var. local (25.7, 1.37 and 6.28 kg NPK ha^{-1}), maize + red gram var. BRG-1(16.81, 0.60 and 3.60 kg NPK ha^{-1}) and maize + red gram var. Hyd-3c (18.32, 0.71 and 3.60 kg NPK ha^{-1}). This may be attributed to the higher quantity of litter fallen in these treatments as both field bean and red gram occupied the land for long duration (Table 1).

The soil pH was influenced significantly by various maize based intercropping systems (Table 3). The higher pH was observed with different intercrops sown at pure stand when compared to that of intercrop and also to sole crop of maize (5.10). 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 was on par all other sole crop treatments of pulses and significantly higher than sole crop of maize (5.1). It was also observed that pH recorded with different intercrop was numerically higher than pH recorded with sole maize plot except with maize + field bean var. HA-3 (4.9). The data on electric conductivity indicated that there was no appreciable change in EC of soil under different intercropping systems. However, almost all intercrop treatments except maize + red

Table 1. Amount of litter produced and nutrients recycled as a result of litter fall as influenced by different intercropping systems

(Mean of two years)

Treatments	Litter fall (kg ha^{-1})	Nutrients added (kg ha^{-1})		
		N	P	K
T_1 Sole maize at URS of 60 cm	0 (1.05)	0 (1.0)	0 (1.0)	0 (1.0)
T_2 Sole maize at PR of 45-75-45 cm	0 (1.08)	0 (1.0)	0 (1.0)	0 (1.0)
T_3 Sole soybean (Vr. KHSb 2)	286.3 (16.9)	5.47 (2.54)	0.26 (1.17)	1.14 (1.46)
T_4 Sole soybean (Vr. KB- 79)	239.5 (15.4)	4.73 (2.39)	0.22 (1.09)	0.88 (1.37)
T_5 Sole red gram (Vr. Hyd- 3c)	1609 (40.1)	27.03 (5.29)	1.03 (1.43)	5.31 (2.51)
T_6 Sole red gram (BRG -1)	1677 (42.0)	30.2 (5.56)	0.97 (1.43)	6.36 (2.71)
T_7 Sole field bean (Var.- HA_3)	343.8 (18.5)	6.4 (2.72)	0.29 (1.13)	1.10 (1.43)
T_8 Sole field bean (Local Avare)	2100 (45.5)	39.5 (6.33)	1.41 (1.76)	9.66 (3.25)
T_9 French bean (Var. Arka Komal) Vegetable	293 (17.0)	5.98 (6.62)	0.38 (1.17)	0.82 (1.35)
T_{10} French bean (Var. Arka Komal) Grain	263 (16.1)	5.37 (2.51)	0.29 (1.13)	0.74 (1.32)
T_{12} Maize (PR) + Soybean var. KHSb-2	160 (12.6)	13.05 (3.01)	0.14 (1.07)	0.64 (1.28)
T_{13} Maize (PR) + Soybean var. KB- 79	150 (12.3)	2.92 (1.98)	0.12 (1.06)	0.55 (1.25)
T_{14} Maize (PR) + Red gram var. Hyd - 3c	1092 (33.0)	18.32 (4.39)	0.71 (1.31)	3.60 (2.14)
T_{15} Maize (PR) + Red gram var. BRG-1	995 (31.5)	16.81 (4.21)	0.60 (1.26)	3.60 (2.14)
T_{16} Maize (PR) + Field bean var. HA- 3	162 (12.7)	3.02 (2.00)	0.13 (1.06)	0.48 (1.22)
T_{17} Maize (PR) + Field bean var. Local	1366 (36.8)	25.7 (5.14)	1.37 (1.54)	6.28 (2.69)
T_{18} Maize (PR) + French bean var. Arka Komal V)	191 (13.7)	3.89 (2.2)	0.21 (1.10)	0.53 (1.24)
T_{19} Maize (PR) + French bean var. Arka Komal (G)	139 (11.7)	84 (1.95)	0.15 (1.07)	0.48 (1.21)
S.Em.±	0.98	0.13	0.22	0.55
C.D. at 5%	2.72	0.36	0.62	0.152

URS-Uniform Row Spacing, PR- Paired Row System, Figures in the parentheses are $\sqrt{x+1}$ values

Table 2. Nutrient content of litter material of different intercrops

Litter material	N (%)	P (%)	K (%)
Field bean var. local	1.88	0.100	0.46
Field bean var. HA-3	1.86	0.080	0.16
Soybean var. KHSb-2	1.91	0.085	0.40
Soybean var. KB-79	1.93	0.080	0.37
Red gram var. Hyd-3c	1.68	0.065	0.33
Red gram var. BRG-1	1.69	0.060	0.36
French bean var. Arka Komal	2.04	0.110	0.28

gram var. BRG-1 (0.16 dS m^{-1}) recorded significantly higher EC than sole crop of maize (0.014 dS m^{-1}) sown at URS (Table 3).

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 soil organic carbon was recorded with the treatments maize + field bean var. local (0.573) followed by maize + red gram (0.533). 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 ha^{-1}) was observed with treatments having pulse crop compared to no litter fall under maize sole cropping (Table 1) justify the changes in organic carbon status (Table 3). The results are in line with findings of Wikson Makumbe *et al.* (2007) who reported that maize + glyricidia intercropping system could sequester more C than sole maize. Further, Wani and Lee (1995) reported (67% in 22 years) the higher carbon content in the top 15 cm soil layer in case of pigeonpea based intercropping system as compared to non legume system. Paustian *et al.* (1997) recorded higher soil carbon input with the continuous cropping, particularly when fertilizers were applied and legumes were included in the system.

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

Treatments	pH (dS m^{-1})	EC	Organic carbon (%)	Available nutrients (kg ha^{-1}) N	P_2O_5	K_2O	Maize equivalent yield (kg ha^{-1})
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. at 0.05%	0.38	0.0036	0.051	14.1	3.28	22.2	287.6

URS- Uniform Row Spacing, PR- Paired Row System

The available, N, P and K in soil after harvest of the crops varied with the kind of intercrops. In the present 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. Higher available soil nitrogen and reduced available P and K content was reported when fertilizers were applied only to main crop of maize by Padhi and Panigrahi, 2006 in maize based intercropping system. The data showed that the higher available nitrogen was noticed in plots with sole pulses than sole 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}). All the intercropping 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}) 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. This might also be due to residual effect of added fertilizer nutrients to respective crops as per recommendation based on population in intercropping systems. These results are in conformity with findings of Rutherford and Juma (1989). Significant increase in available soil nitrogen was also observed by Padhi and Panigrahi (2006) in their study on maize based intercropping systems wherein irrespective of row ratios at initial and post-harvest available soil N content than sole maize. The available soil P recorded with 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 decomposition of organic matter in legume cropping systems could also be the reason for higher available P. Inal *et al.* (2007) reported significantly higher acid phosphatase activity in rhizosphere of intercropped maize than sole cropping of 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}) 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 intercrops was higher than their respective intercropping systems (Table 3). Increased biological and chemical activity in rhizosphere might have resulted in higher available nutrients under sole crop of pulses and intercropping systems (Inal *et al.,* 2007). The highest soil organic carbon content was recorded with the treatment maize + field bean var. local followed by maize + red gram. All intercropping treatments recorded higher available nutrients than sole crop of maize, the highest being noticed in plot grown with maize + field bean (local) and maize + red gram. Thus, intercropping maize with field bean, red gram and other pulses helps in improving soil fertility as compared to sole crop of maize.

The data on maize equivalent yield pooled over two 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. This may be assigned to the synergetic effect of maize and field bean in utilization of 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 with maize were also the cause for higher maize equivalent yield in these treatments. Similarly, Shivay *et al.* (1999) have observed higher maize equivalent yield with maize + urdbean/soybean intercropping system over sole maize.

References

Inal, A., Gunes, A., Zang, F. and Cakmak, I., 2007, Peanut/maize intercropping induced changes in rhizopsphere and nutrient concentrations in shoots. *Plant Physiol. & Biochem.,* 45(5): 350-356.

Padhi, A .K. and Panigrahi, R. K., 2006, Effect of intercrop and crop geometry on productivity, economics, energetics and soil-fertility status of maize (*Zea mays*) based intercropping systems. *Indian J. Agron.,* 51(3): 174-177.

Paustian, K., Agren, G. and Bosatta, E., 1997, Modelling litter quality effects on decomposition and soil organic matter dynamics. In: *Driven by Nature: Plant Litter Quality and Decomposition,* (Eds. Cadisch, G. and Giller, K.E.), CAB International Wallingford, pp. 313-336.

Rutherford, P. M. and Juma, N. G., 1989, Shoot, root, soil and microbial nitrogen dynamics in two contrasting soils cropped to barley (*Hordeum vulgare* L.). *Biol. Fertl. Soils,* 8: 134-143.

Shivay, Y. S., Singh, R.P. and Pandy, C. S., 1999, Response of nitrogen in maize based intercropping system. *Indian J. Agron,* 44: 261-266.

Wilkson Makumbe, Festus, K. Akinnifesi, Bert Janssen and Oene Oenema, 2007, Long-term impact of a glircidia-maize intercropping system on carbon sequestration in Southern Malawi. *Agric. Ecosyst. Environ.,* 118(1-4): 237-243.

Wani, S. P. and Lee, K. K., 1995, Role of microorganism in sustainable agriculture. In: *Plant Microbes Interaction in Sustainable Agriculture,* CCSHAU, Hissar, India.