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Research Communication

Soil properties and nutrient uptake as influenced by mulching in maize (*Zea mays*)-based cropping systems

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ABSTRACT

A field experiment was conducted at the ICAR Research Complex for NEH Region, Umiam, Meghalaya (950 m above sea-level) during the rainy (*kharif*) and winter (*rabi*) seasons of 2012–13, to study the effect of soil-moisture conservation (SMC) measures on nutrient uptake and soil fertility in maize (*Zea mays* L.)-based cropping sequences. Significantly the highest soil organic carbon (SOC) was recorded under maize–French bean (*Phaseolus vulgaris* L.) (pole type) system (1.72%) followed by maize–blackgram [*Vigna mungo* (L.) Hepper] (1.70%) at 0–15 cm depth. *In-situ* maize stover mulch (MSM) + white hoarypea (*Tephrosia candida* DC.) @ 10 t/ha (on fresh weight basis) mulch resulted in significantly higher SOC (1.72%), followed by MSM + ragweed (*Ambrosia artemisiifolia* L.) mulch 10 t/ha (1.69%). The highest soil available N (268.6 kg/ha) and P (15.7 kg/ha) were recorded under maize–blackgram and K (277.6 kg/ha) under maize–French bean cropping system. The MSM + *Tephrosia* mulch recorded significantly higher soil available N, P and K, followed by MSM + *Ambrosia*. Maize–French bean (pole type) cropping system had significantly higher soil microbial biomass carbon (SMBC; 258.55 μg/g soil) and dehydrogenase activity (DHA; 37.27 μg TPF/hr/g) than that under maize–fallow. Among the SMC measures, MSM + *Tephrosia* recorded the maximum SMBC (265.75 μg/g soil) and DHA (34.27 μg TPF/hr/g) followed by MSM + *Ambrosia.* On an average, nutrient (N, P and K) content and uptake in seed and stover of all the *rabi* crops were the highest under MSM + *Tephrosia* followed by MSM + *Ambrosia* system. The highest maize-equivalent yield was obtained from maize–Frenchbean (pole type) system under MSM + *Tephrosia* mulch (9.5 t/ha), followed by MSM + *Ambrosia* mulch (8.8 t/ha).

Key words : Cropping systems, Maize equivalent yield, Mulch, Nutrient uptake, Soil fertility, Soil-moisture conservation,

In North-Eastern region (NER) of India, maize is the second most important foodgrain after rice. Maize is mostly grown under rainfed condition in upland and *jhum* lands. The region receives enough rainfall (>2,000 mm annually), most of which is concentrated in monsoon season. In Meghalaya, more than 84% of annual rainfall is received during May–October, and November to March is the dry period. Lack of irrigation facilities makes it more complex for providing any supplemental irrigation to winter (*rabi*) season crops. After harvesting of the rainy (*kharif*) crops, lack of sufficient soil-moisture availability limits the cultivation of winter (*rabi*) crops in uplands. Blackgram, greengram, rapeseed, French bean, lentil etc. can be cultivated in upland after maize with conserved soil moisture or life-saving irrigation. In NER, maize stalk are not used as fodder for animals but are usually burnt or kept outside the field. During the rainy season, owing to favourable climate, there are plenty of weeds and shrubs around cultivated areas or road sides which are luxuriant in growth and difficult to control. The crop residues and weed biomass could be effectively utilized as mulch for *in-situ* soil-moisture conservation. Tilling the soil after the *kharif* crop results in loss of conserved moisture. Thus, no-till is a viable option in conserving moisture besides saving energy, promoting soil health, facilitating timely sowing of second crop and reduction in cost of cultivation (Ghosh *et al*., 2010). The present study was conducted to

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assess the impact of maize-based cropping sequences and mulching practices on soil properties and nutrient removal in mid altitude of Meghalaya.

The field experiment was conducted during the rainy and winter seasons of 2012–13 at the upland Agronomy Farm of Indian Council of Agricultural Research (ICAR), Research Complex for NEH Region, Umiam, at (25°41' N and 91°54' E 980 m above mean-sea level), Meghalaya. The total rainfall received during crop period was 2052.5 mm, of which the highest rainfall was received in August (440 mm) and no rain in December**.** The total evaporation recorded during the entire period was about 680 mm, in which the highest evaporation was recorded during April (107.9 mm) and the lowest during December (46.8 mm). Mean maximum monthly temperature was recorded during May (29.16° C) and the minimum in December (21.04° C). The soil was sandy clay loam, having soil *p*H 5.24, soil organic carbon (SOC) 1.59% and bulk density 1.17 Mg/m^3 at 0–15 cm depth. Soil was low in available N and P and medium in K.

Five maize-based cropping sequences, viz. maize–fallow, Maize–rapeseed (*Brassica napus* L.), Maize–bush type French bean (*Phaseolus vulgaris* L.) (BT), Maize–Pole type French bean (PT) and Maize–blackgram [*Vigna mungo* (L.) Hepper], were assigned to main plots and 4 mulching (soil-moisture conservation) measures, i.e. no mulch (residue removal), *in-situ* maize stover mulch (MSM), MSM + ragweed (RW) (*Ambrosia artemisiifolia* L.), and MSM + [white hoary pea (WHP)] (*Tephrosia candida* DC.) were allotted to subplots. The RW and WHP mulches were applied @ 10 t/ha on fresh weight basis.

The field experiment was laid in a split-plot design and replicated thrice. Maize cultivar 'DA 61 A' was sown on 30 April 2012 with all the recommended agronomic practices [fertilizer 60:60:40 kg/ha N : P_2O_5 : K_2O (N was applied in 2 splits, first half as basal and remaining at knee-height stage), FYM 5 t/ha, spacing 60 cm × 20 cm, gap filling at 10 days after sowing (DAS), 2 hand-weedings at 25 and 45 DAS]. Roundup 3 G was applied for managing insect-pests such as stem-borer. The fresh biomass of RW and WHP were collected from nearby areas (road sides, wastelands, farm fences etc.). The upper tender portions of these plants were retained, discarding the woody lower portion of stems which take more time to decompose. The fresh biomass was weighed and applied as mulch in between the rows of standing maize 20 days before harvesting of maize (9 August) as per the treatment requirement. Glyphosate (Round up) 75.7% at the rate of 3 ml/liter was applied to make the field weed-free before harvesting of maize. After harvesting of maize, furrows were opened between 2 maize rows using a manual furrow opener by pushing the mulches on the side of maize rows to sow the winter (*rabi*) crops. Thus, row to row spacing for winter. The recommended doses of fertilizers (60 : 60 : 40 N : P_2O_5 : K_2O kg/ha for rapeseed, 50 : 60 : 40 kg/ha for French bean pole and bush type and 20 : 60 : 40 kg/ha for blackgram), and seeds were placed in the furrows and covered with soil and the mulch materials were adjusted to cover the surface. French bean [bush (cv. 'Arka Anoop') and pole type (cv. 'Naga Local')] and blackgram (cv. 'Pahenlo dal 4') were sown on 24 August 2012. However, rapeseed cv. 'TS 46' was sown on 21 September 2012. After the germination, the standing maize stalks were cut at the base and spread all over the field just above the mulches to cover the soil surface. Two hand-weedings were given [20 and 40 days after sowing (DAS) for all *rabi* crops except rapeseed for which weeding was done on 25 and 50 DAS] and weed biomass was retained along with mulches *in situ* for soil-moisture conservation. The gross and net plot sizes were 4 m × 3 m and 3 m × 2.5 m^2 respectively.

At maturity, seed yields were recorded from the net plot area after sun drying to about 14% moisture content. All the yields were converted to maize-equivalent yield (MEY) for comparison of treatments. Soil samples were collected before maize sowing and after harvesting of *rabi* crops from 0–15 cm depth**.** The soil *p*H, SOC, available N, P and K, were determined following standard procedure. The bulk density was determined by core method after harvesting of *rabi* crops. Water-holding capacity (WHC) was measured after the harvesting of *rabi* crops. Soil microbial biomass carbon (SMBC) was estimated by the chloroform fumigation method. The SMBC was calculated with the difference between fumigated and non-fumigated samples and divided by the K_2SO_4 efficiency factor (KE_C = 0.38) and expressed as µg/g soil. Dehydrogenase activity (DHA) in soil was determined by Triphenylformazan (TPF) reduction method. The plant samples for each crop were analyzed separately for total N (modified Kjeldahl's method), P (di-acid digestion and yellow colour development method), and K (flame photometric method). The respective per cent content of different nutrient were multiplied by corresponding dry-matter yield to estimate the nutrient uptake (removal) and expressed in kg/ha. Critical difference (CD) at 5% probability (P=0.05) were worked out for each parameter studied to evaluate differences between treatment means.

Significant effect of cropping systems and mulching measures were observed on SOC, available N, P and K (Table 1). The highest SOC was recorded under maize–French bean (PT) (1.72%), followed by maize–blackgram system (1.7%). The higher SOC in maize–blackgram system might be owing to presence of higher soil-moisture content that increased the microbial population and hastened the decomposition of crop residues in building up of organic carbon in soil. Adiku *et al*. (2008) reported increase in potential mineralisable carbon owing to inclusion of legume in cropping systems. Higher SOC was recorded under MSM + *Tephrosia* (1.73%), followed by MSM + *Ambrosia* mulch (1.69%). The increase in SOC under retention of maize stalk mulch along with *Tephrosia*/*Ambrosia* may be owing to decomposition of mulch material that added some organic matter in the soil.

Among the cropping systems, the highest soil available N (268.6 kg/ha) was recorded after maize–blackgram as compared to other cropping systems (Table 1). There was 10% higher soil available N after maize–blackgram than maize–fallow system. This might be owing to biological nitrogen-fixing ability of leguminous crop that left varying amount of N in soil and increased soil-available N. The soil-available N was higher under mulched plot than that under residue removal (Table 1). The highest soil available N was found under MSM + *Tephrosia* mulch (268.2 kg/ha), followed by MSM + *Ambrosia* mulch. This might be because of addition of some nutrient from *Tephrosia* or *Ambrosia* after mineralization which decompose completely within 45 days and supply some nitrogen to the soil (Laxminarayan *et al*., 2006). The enhanced conservation of moisture in the soil profile owing to mulching might have resulted in greater available N (Sharma *et al*., 2010). The interaction effect of cropping systems and SMC indicated that the highest soil available N was recorded in maize–blackgram system under MSM + *Tephrosia* mulching (277.68 kg/ha). The direct effects of live mulching on maize might be less pronounced but the residual effects on the following crops were larger because of enhancement in soil moisture and nutrient supply (Sharma *et al*., 2010).

The highest available P was found after maize–blackgram (15.7 kg/ha), followed by maize–rapeseed system. The higher available P after maize–blackgram system might be owing to growing of leguminous crop that increased SOC and in turn improved the soil available P (Roldan *et al*., 2003). Higher soil available P was also recorded under MSM + *Tephrosia* mulch, followed by MSM + *Ambrosia* mulch in both the depths. The higher amount of available P could be owing to application of residues and hedge leaves biomass which reduce the fixation of water-soluble P and increased the mineralization of organic P because of microbial action and thus, enhanced availability of P (Prasad *et al*., 2010). Significant interaction of cropping system and SMC measures was recorded in soil available P at all soil depth (Table 1). The highest soil- available P was found in maize–rapeseed system grown under MSM + *Tephrosia* mulching.

Table 1. Effect of cropping systems and mulching measures on soil chemical properties after harvesting of winter (*rabi*) crops

Treatments	SOC (%)	Available nutrients (kg/ha)			WHC (%)	Bulk density (Mg/ m^3)	SMBC (μg/g soil)	DHA (μg TPF/hr/g)
		N	P	K				
Cropping systems								
Maize–Fallow	1.59	242.0	12.3	249.7	68.9	1.28	238.5	28.2
Maize–Rapeseed	1.67	257.3	15.6	273.4	71.9	1.25	248.3	29.2
Maize–French bean (BT)	1.68	259.9	12.9	275.5	71.23	1.28	249.8	32.0
Maize–French bean (PT)	1.72	255.5	12.0	277.6	72.1	1.27	258.6	37.3
Maize–Blackgram	1.70	268.6	15.7	248.4	74.2	1.24	255.8	31.3
SEm±	0.02	4.12	0.58	2.67	1.06	0.01	4.49	1.29
CD (P=0.05)	0.07	13.43	1.88	8.71	3.42	0.03	NS	4.20
Mulching measures								
No mulch	1.60	245.4	11.5	254.7	68.3	1.27	233.0	29.4
In-situ Maize stover mulch (MSM)	1.65	252.5	13.1	262.0	71.5	1.26	243.3	30.7
MSM + *Ambrosia*	1.69	260.6	14.5	268.9	72.4	1.27	258.7	31.9
MSM + *Tephrosia*	1.73	268.2	15.7	274.1	74.5	1.25	265.8	34.3
SEm±	0.01	1.15	0.44	1.70	1.34	0.01	2.93	1.10
CD (P=0.05)	0.04	3.71	1.42	5.49	4.33	NS	9.46	3.54
SMC at same or different level of cropping system								
SEm±	0.03	4.68	1.03	4.24	2.80	0.02	7.24	2.43
CD (P=0.05)	0.10	14.88	3.10	NS	NS	0.05	NS	7.42
CS at same or different level of soil moisture conservation								
SEm±	0.03	2.57	0.99	3.80	3.00	0.02	6.55	2.45
CD (P=0.05)	0.09	7.42	2.85	NS	NS	0.05	NS	7.08

BT, bush type; PT, pole type; WHC, water-holding capacity; SMBC, soil microbial biomass carbon; DHA, dehydrogenase activity

Soil-available K was the highest under maize–French bean (PT) system (277.6 kg/ha), followed by maize–French bean (BT) cropping system. MSM + *Tephrosia* mulch recorded the highest soil-available K. This may be because of high amount of biomass maintained at the surface as mulching material, comprising both maize stalk and *Tephrosia*/*Ambrosia* mulch (Prasad *et al.,* 2010).

Maximum WHC (Table 1) was observed in soils under maize–blackgram, followed by maize–French bean (PT). The MSM + *Tephrosia* had significantly the highest WHC that was at par with MSM + *Ambrosia* mulching. Mulching promotes the activity of soil microorganisms and soil aggregation, thereby improve soil structure and increase soil water content. Soils under maize–blackgram system recorded the lowest soil bulk density (1.24 Mg/m^3), followed by maize–rapeseed system. In case of mulching measures, no-significant effect on bulk density was observed at all the depths (Table 1). The highest bulk density was recorded in soils under residue removal at all depths and the minimum bulk density was observed where MSM + *Tephrosia* mulch was applied as mulch. Interaction of cropping system and SMC measures on WHC revealed that the maximum WHC was under maize–blackgram (78.53 %) and maize-rapeseed (77.26%) system along with MSM + *Tephrosia* mulch.

The SMBC was highest (Table 1) in soils under maize–French bean (PT) system (258.55 μg/g soil) followed by maize–black gram. The SMBC was the highest in soils under MSM + *Tephrosia* mulch (265.75 μg/g soil), followed by MSM + *Ambrosia*. The increase in SMBC and soil respiration can be attributed to the incorporation of easily degradable mulch materials which stimulates the microbial activity (Tejada abd Gonzalez, 2006). Significantly higher DHA (Table 1) was recorded in soils under maize–French bean (PT) (37.27 μg TPF/h/g), followed by maize–French bean (BT) system. This might be owing to inclusion of legumes (French bean) in the cropping systems (Roldan *et al*., 2003). Higher DHA was recorded under MSM + *Tephrosia* mulch, followed by MSM + *Ambrosia* mulch as compared to no mulch. The higher DHA under MSM + *Tephrosia* mulch might be owing to decomposition of maize stalk and weed biomass where residues of maize had higher C : N ratio and easily decomposed by microbes. Higher organic matter present because of residue mulching and increase carbohydrate content which acted as an energy sources or microbes and increase DHA (Roldan *et al.,* 2003).

Interaction effect of cropping systems and mulching

Table 2. Effect of cropping systems and mulching measures on interaction effect on maize-equivalent yield (t/ha)

Treatments	Maize – Fallow	Maize – Rapeseed	Maize – French bean (BT)	Maize – French bean (PT)	Maize – blackgram	Mean
No mulch	3.12	4.31	6.42	7.22	5.58	5.33
In-situ Maize stover mulch (MSM)	3.12	4.53	6.59	8.01	6.25	5.7
MSM + *Ambrosia*	3.12	4.56	7.14	8.83	6.93	6.12
MSM + *Tephrosia*	3.12	4.75	7.94	9.50	7.46	6.55
Mean	3.12	4.54	7.02	8.39	6.55	
Interaction	SEm±	CD (P=0.05)				
Cropping systems (CS)	0.09	0.30				
Mulching measures (MM)	0.05	0.18				
MM at same or different level of CS	0.14	0.43				
CS at same or different level of MM	0.12	0.35				

BT, bush type; PT, pole typ

Table 3. Effect of soil-moisture conservation measures on total N, P and K uptake (seed + stover) by winter crops after maize

Treatment	Rapeseed (kg/ha)			French bean (bush type) (kg/ha)			French bean (pole type) (kg/ha)			Blackgram (kg/ha)		
Soil, moisture conservation measures	N	P	K	N	P	K	N	P	K	N	P	K
No mulch	28.3	2.75	25.9	33.2	2.75	19.6	42.6	3.63	23.0	46.9	3.03	25.2
In-situ maize stover mulch (MSM)	33.8	3.23	32.2	35.9	3.23	21.4	51.2	4.67	27.2	61.7	4.21	32.6
MSM + *Ambrosia*	36.0	4.24	35.1	41.7	4.24	25.2	58.8	6.11	32.0	74.4	5.66	39.6
MSM + *Tephrosia*	40.5	4.82	39.8	49.3	4.82	29.1	65.2	6.63	35.1	84.8	6.90	44.9
SEm±	0.65	0.16	0.47	1.12	0.16	0.43	2.15	0.29	1.18	1.81	0.24	0.98
CD (P=0.05)	2.27	0.54	1.63	3.87	0.54	1.49	7.46	0.99	4.10	6.25	0.83	3.40

measures on MEY (Table 2) indicated that the maximum MEY was obtained under maize–French bean (PT) cropping system with the retention of maize stalk mulch along with *Tephrosia* mulch (9.5 t/ha), followed by MSM + *Ambrosia* mulch. The MEY under MSM + *Tephrosia* mulch were significantly higher than that under no mulch for all the cropping sequences. In general, maize– French bean (PT or BT) sequences recorded significantly higher MEY than those recorded under maize–black gram, maize–rapeseed or maize–fallow sequences. Das *et al*. (2015) reported increase in system productivity owing to residue retention and mulching than no mulching from NER of India.

Nutrient content and nutrient uptake by *rabi* crops were significantly influenced by mulching measures (Table 3). Higher nutrient uptake was found under MSM + *Tephrosia* mulch, followed by MSM + *Ambrosia* mulch in all the crops. The nutrient uptake by rapeseed, French bean (BT), French bean (PT) and blackgram were 43, 48, 53 and 81% higher under MSM + *Tephrosia* mulch than no mulch respectively. Various mulching practices help in the conservation of soil moisture in the root zone profile; this enhanced root proliferation and availability of nutrients to crop roots. The higher nutrient uptake may also be attributed to the possible improvement in soil thermal regimes owing to mulching which gives a more favourable environment for the growth and development of the crop. The high nutrient uptake by blackgram might be attributed to its higher dry matter as well as high nutrient content in biomass.

Thus, maize–French bean cropping system enhanced the system productivity and maize–blackgram and maize–French bean systems improved the soil properties compared to maize–fallow system. Mulching measures MSM + *Tephrosia* and MSM + *Ambrosia* were found beneficial for improving soil properties and enhancing system productivity in hill ecosystems of Meghalaya, North East India.

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