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Effect of mulching on maize and wheat (*Triticum aestivum*) in maize-wheat cropping system

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Abstract: A field experiment was carried out in deep black soils under rainfed conditions for two consecutive years during *kharif* and *rabi* season of 2013-14 and 2014-15 to study the performance of rabi wheat as influenced by mulching practices in maize-wheat cropping system. The experiment comprised of two vertical strip treatments *viz., kharif* maize grown with mulch and without mulch and horizontal sub plot treatments *viz. rabi* wheat with mulch and without mulch. The growth parametes, yield parameters, yield of wheat and available moisture and economics varied significantly among the mulching practices. All the growth parameters *viz.,* plant height, number of effective tillers per meter row length, leaf area, dry matter production; yield parameters *viz.,* grain weight per ear, test weight and grain and straw yield of wheat were significantly higher with mulching to preceding *kharif* maize followed by wheat with mulching. It also recorded the highest total N, P and K uptake in wheat. The apparent recovery efficiency, agronomic efficiency of N and P were higher with that treatment. The economic analysis also revealed that the maximum benefits could be obtained from both seasoned mulch as compared to without mulch treatment. Benefit-cost ratio was highest in both season mulch and was lowest in without mulch any of the crops in sequence. All the mulch treatments improved the available moisture status in soil. The highest soil moisture was observed in both season mulched wheat. The residual soil moisture was minimum in both season mulched wheat, indicating effective utilization of moisture by the crop under that treatment.

Key words*:* Cropping system, Economics, Grain yield, Mulching, Nutrient uptake

Introduction

Maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system is one of the major cropping systems in India, covering around 1.8 million ha mainly in Indo-Gangetic Plains of India. Maize is considered as a most important option for diversifying agriculture in upland areas of India. Wheat, is another major important staple cereal, supplies the bulk of calories and nutrients in the diets of a large proportion of the world population (Singh *et al.,* 2010). This maize-wheat can be a very potential cropping system in the northern transitional tract of Karnataka under semi arid condition in rainfed situations. Vagaries of monsoon coupled with lack of sufficient moisture determines the productivity of this system.

The retention of crop residues on the soil surface is a key factor for reducing surface water runoff and erosion. A mulch of crop residues enhances water infiltration and protect the soil from sealing and crusting by rainfall. Under semi-arid conditions surface crop residues also play an important role in conservation of soil water through reduced soil evaporation. In addition, crop residues as mulch moderate the temperature fluctuation in the top layer, which can enhance the activity of soil microorganisms and fauna, thus promoting the release of nutrients, improving water infiltration and facilitating root development. The water conservation effect of surface residue may potentially increase crop yields in tropical environments faced with risks of drought stress.

The profitability and higher yield of rabi crops mainly depends on stored soil moisture and rainfall after sowing of *rabi* crops. Rainfall after sowing of *rabi* crops in October-November is a chance factor. Therefore, the soil moisture at sowing largely determines the productivity of winter crops with good weather conditions prevailing thereafter. Hence, moisture is the major constraint in crop production during *rabi* season. This constraint can be alleviated by effective moisture conservation practices. The complex interactions between management practices, soil and weather conditions may be addressed to some extent through application of crop residues as mulch on surface mitigating the production risk associated with rainfall variability. Further, the transportation of mulch materials in the crop field may be a critical problem in some areas, thus, in situ generation of different mulch materials is of great significance in rainfed farming.

With this back ground an experiment was conducted for two years to study the effect crop residue used as mulching on performance of wheat, nutrient use efficiency, stored and available moisture and economics in maize-wheat cropping system.

Material and methods

A field experiment was carried out during *kharif* and *rabi* seasons of 2013-14 and 2014-15 at Dharwad, Karnataka, under rainfed conditions to evaluate the effect of mulching practices on the performance in maize-wheat cropping system. The soil of the experimental site was deep black with slightly alkaline reaction (pH 7.3), medium in organic C (0.66%), available N (264 kg/ha), P (P_2O_5 28.54 kg/ha) and high in available K (K_2O 356.8 kg/ha). The experiment was laid out in a strip split plot design with three replications. The data collected from the experiment at different growth stages and at harvest was subjected to statistical analysis. In *kharif* maize was grown with and without mulch in strips and in succeeding *rabi* wheat was sown in each strip with and without mulch. Mulching was done at after first interculture. The quantity of *rabi* crop residues at 0.5 kg m^{-2} (5000 kg ha^{-1}) for maize and at 0.8 kg m^{-2} (8000 kg ha^{-1}) of maize stover were applied to wheat crop. The maize (var. 'Cargill M-900 super gold) was sown on 24th June 2013 and 16th July 2014 in *kharif,* followed by wheat (var.'DWR 2006) sown on 6th November 2013-14 and 09th November 2014-15 in the succeeding *rabi,* respectively. The maize was sown in 7.2 x 40.5 m strips and wheat was sown in 9.5 x 4.5 m and sub sub plot was 7.2 x 4.5 m. The recommended dose of fertilizers were applied to crops (maize, 100 N: 50 P_2O_5:50 K_2O: 15 ZnSo4 kg/ha) and wheat (50 N: 25 P_2O_5:0 K_2O in the form of urea, di-ammonium phosphate and murate of potash). 50% N along with full dose of P and K were applied as basal and the remaining 50% N was top dressed at 30 DAS in both maize and wheat. All the cultural and plant protection measures were adopted as per the state recommendations. The total rainfall received during 2013-14 was 707.6 mm with 63 rainy days, of which 456.20 mm was received during crop period (May to October II nd FN *i.e.,* 24th to 43th Std. week). The monsoon was with drawn early in 2013. This adversely affects the germination and greater reduction in rabi yield. However, the total rainfall received during 2014-15 was 1056 mm in 71 rainy days, of which 490.2 mm rainfall was received during crop period (July to November *i.e.,* uniform distribution from 29th to 50th std week rabi rains exteneded upto November 16th and good rains received in Dec 13th with 26.2 mm.). There was no much variation in case of weather parameters like relative humidity, maximum and minimum temperature in both the years during the cropping season. Five plants were selected randomly from the second row of the each plot for recording plant height and leaf area. 1 m length was selected after leaving the first row of the each plot for the measurement of dry-matter accumulation. Leaf area index was computed by dividing the leaf area to ground area. After harvesting, threshing, cleaning and drying, the grain yield was recorded. Straw yield was obtained by subtracting grain yield from the total biomass yield. The economics was calculated based on prevailing market prices of inputs and produce. Net returns for the crops were computed on the basis of grain and straw yield, their prevailing market prices and cost of cultivation. Benefit: cost ratio was computed by dividing the net returns by total cost of cultivation. The soil samples were drawn at weekly intervals and moisture was estimated by gravimetric method. The available water content was computed by deducting the permanent wilting point from the field capacity using the following formulae.

$$\text{Soil moisture (\%)} = \frac{\text{Wet soil sample - Dry soil sample}}{\text{Dry soil sample}}$$

Available water content (%) =Field capacity - Permanent wilting point

Total nitrogen, phosphorous and potassium uptake of wheat were calculated for each treatment separately using the following formula and the uptake of N, P and K were expressed in kg/ha.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Per cent nutrient concentration}}{100} \times \text{biomass (kg/ha)}$$

Nutrient use efficiency was measured throught Apparent Recovery (AR) and Agronomic Efficiency (AE). These parameters were computed using the following formulae.

$$AR_{N/P/K}(\%) = \frac{\text{Total N/P/K uptake fromTreated plot (kg/ha)} - \text{Total N/P/K uptake fromcontrol plot (kg/ha)}}{\text{Amount of N/P/K applied (kg/ha)}} \times 100$$

$$AE_{N/P/K}(\text{kg ha}^{-1}) = \frac{\text{Grain yield in treated plot (kg/ha)} - \text{Grain yield in control plot (kg/ha)}}{\text{Amount of N/P/K applied (kg/ha)}}$$

Results and discussion

Yield and yield attributes of *kharif* maize

Mean of two years data indicated that maize grown with mulching practices recorded significantly higher grain yield (8345 kg ha^{-1}), yield parameters like, test weight (40.83 g), cob length (21.09 cm), grain weight per plant (172.5 g), gross returns (₹ 109316 ha^{-1}) and net returns (₹ 74021 ha^{-1}) as compared to without mulching practices (Table 1 and 2).

Table 1. Grain yield (kg/ha) and yield parameters of maize as influenced by mulching practices

Treatments	Test weight (g)			Cob length (cm)			Grain weight (g $plant^{-1}$)			Grain yield (kg ha^{-1})		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Maize with mulch	37.70	43.95	40.83	19.28	22.89	21.09	164.53	180.62	172.57	8156	8533	8345
Maize without mulch	32.74	39.48	36.11	17.26	19.50	18.38	143.75	174.49	159.12	6758	7652	7205
Table 't'	2.776	2.776	2.228	2.776	2.776	2.228	2.776	2.776	2.228	2.776	2.776	2.228
Cal 't'	6.099	5.379	2.224	2.905	3.716	2.510	22.826	6.309	1.729	7.747	10.834	4.862
Test of significance @ 0.05%	S	S	NS	S	S	S	S	S	NS	S	S	S

Table 2. Economics as influenced by mulching practices

Treatments	Gross returns (₹/ha)			Net returns (₹/ha)			B:C		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Maize with mulch	106844	111789	109316	75700	72342	74021	3.43	2.83	3.13
Maize without mulch	88525	100243	94384	59736	64336	62036	3.07	2.79	2.93
Table 't'	2.776	2.776	2.228	2.776	2.776	2.228	2.776	2.776	2.228
Cal 't'	7.747	10.83	4.862	6.751	7.512	6.958	4.479	1.481	1.305
Test of significance @ 0.05%	S	S	S	S	S	S	S	NS	NS

Growth attributes of wheat

Wheat grown with mulch to preceding maize and succeeding wheat treatment recorded significantly higher plant height at harvest as compared to without mulch treatment (control) (Table 3). The same treatment also recorded significantly higher number of effective tillers as seen in pooled analysis as compared to control. Similar trend was observed in individual years. The development of sound photosynthetic structure in the early period of crop growth of wheat was improved significantly with mulched plot mainly due to higher availability of moisture and nutrients to the crop. Increase in plant height with mulching treatment is attributed to soil moisture conservation and its availability in mulched treatment Mulch cover reduces evaporation losses from soil surfaces, thus increasing moisture availability for plant growth and development. This contributed to better crop stand and this effect is reflected in the number of total tillers per unit area.

Both seasoned mulched treatment recorded significantly higher leaf area and LAI at 90 DAS, in pooled analysis as compared to no mulching to either of the crops in the system. Total dry matter production was significantly higher in *kharif* and *rabi* mulch treatment as compared to control at harvest. Dry matter production and its accumulation in the reproductive parts invariably depend on the magnitude and persistence of photosynthetic capacity of the plant. Photosynthetic capacity of the plant is reflected on the dry matter accumulation in leaves and LAI. The results of present study are in conformity with the findings of Rahman *et al.* (2005) and Kumar *et al.* (2009).

Yield attributes and yields of wheat

Significantly higher grain weight and test weight were recorded both in *kharif* and *rabi* mulch treatment as compared to without mulch (Table 3). Application of mulch both during *kharif* and *rabi* crops recorded significantly higher wheat grain yield and straw yield as compared to without mulch, mulching to either of the crop. However, it was at par with treatment which received mulch only during *rabi* season. The effect of mulching was more pronounced during 2013-14 in both season mulched crop. The per cent increase was 71.44 (0.53 t/ha) over non mulched crop and 27.44 per cent (0.27 t/ha) over only *kharif* season mulch. The increase in yield of mulched plots is the cumulative effect of yield per unit which in turn depends on yield parameters *viz.,* grain weight/ear, no. of grains per ear and test weight. The increase in yield in mulched treatment was due to higher availability of stored moisture from soil profile till harvest (Fig 1). These results are in conformity with the findings of Chakraborty *et al.* (2010). Greater soil moisture retention and moderated soil thermal regime under organic mulches resulted in higher grain yield. Increased yield in wheat under mulch has also been reported by other researchers too (Xie *et al.,* 2005).

Nitrogen, phosphorous and potassium uptake of wheat

Nitrogen uptake was significantly influenced due to mulching treatments. Application of mulch during both *kharif* and *rabi* recorded significantly higher nitrogen, phosphorous and potassium uptake at harvest stage in pooled analysis as

Table 3. Growth attributes of wheat as influenced by mulching practices

Treatments	Plant height (cm) at harvest			Number of effective tillers (meter^{-1} row length) at 90 DAS			Leaf area (dm^2 m^{-1} row length) at 90 DAS			Leaf area index at 90 DAS			Total dry matter production (g m^{-1} row length) at harvest		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Maize fb wheat without mulch (control)	63.5	67.7	65.6	93	108	100.5	52.54	55.58	54.06	1.75	1.85	1.80	117.46	123.40	120.43
Kharif maize grown with mulch fb wheat without *kharif* mulch in *rabi*	64.2	69.4	66.8	95	116	105.5	56.13	57.50	56.82	1.87	1.92	1.89	124.53	131.57	128.05
Kharif maize without mulch fb wheat with *kharif* mulch	68.5	71.3	69.9	105	119	112	56.84	59.55	58.19	1.90	1.99	1.94	127.40	134.64	131.02
Kharif maize grown with mulch fb wheat with *kharif* mulch	70.6	73.3	71.9	110	120	115	58.84	61.91	60.37	1.96	2.06	2.01	127.44	137.77	132.60
S.Em±	1.27	0.95	1.08	2.09	1.29	1.68	0.87	0.56	0.47	0.02	0.03	0.02	1.42	2.41	1.45
C.D. at 5%	4.40	3.28	3.74	7.23	4.47	5.82	3.01	1.95	1.63	0.07	0.11	0.06	4.92	8.33	5.01

NS – Non-significant fb – followed by

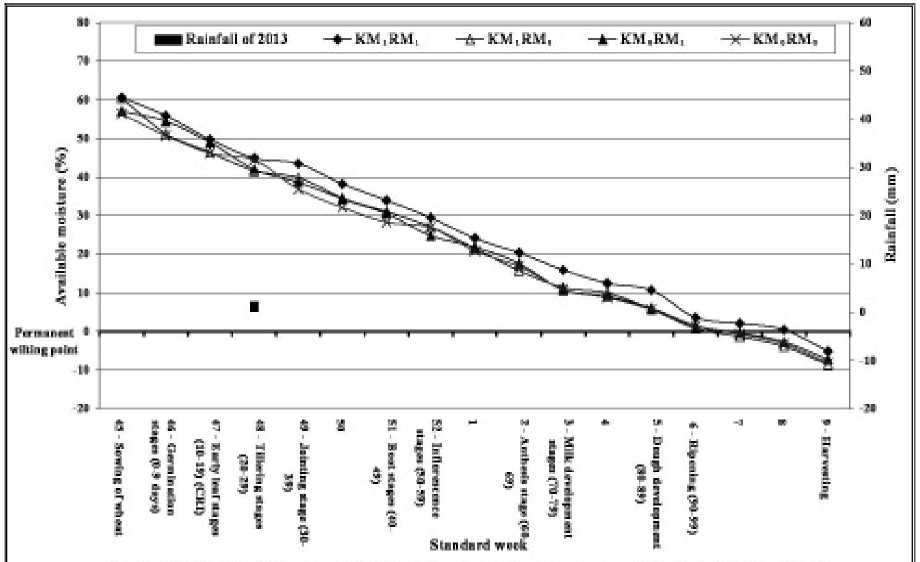

Fig. 1: Effect of mulching on available moisture in wheat crop during 2013-14 at 0-15 cm depth

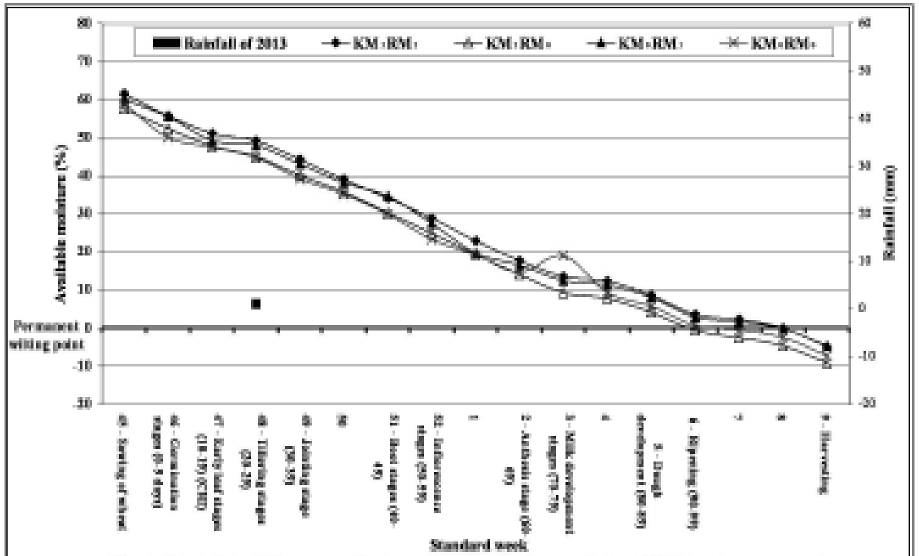

Fig. 2: Effect of mulching on available moisture in wheat crop during 2013-14 at 15-30 cm depth

Table 4. Yield parameters and yield of wheat as influenced by mulching practices

Treatments	Grain weight/ear (g)			Test weight (1000 seeds weihgt g)			Grain yield (t/ha)			Straw yield (t/ha)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Maize fb wheat without mulch (control)	1.56	1.89	1.73	41.42	45.70	43.56	0.75	1.73	1.24	1.54	3.41	2.48
Kharif maize grown with mulch fbwheat without *kharif* mulch in *rabi*	2.45	3.53	2.99	44.48	49.53	47.01	1.01	1.85	1.43	2.13	3.54	2.83
Kharif maize without mulch fb wheat with *kharif* mulch	2.84	4.03	3.44	45.66	51.88	48.77	1.21	1.99	1.60	2.34	3.87	3.11
Kharif maize grown with mulch fb wheat with *kharif* mulch	3.03	4.22	3.63	48.59	53.55	51.07	1.29	2.17	1.73	2.37	4.21	3.29
S.Em±	0.10	0.10	0.08	1.35	1.44	1.36	0.56	0.72	0.52	91	103	70
C.D. (P = 0.05)	0.36	0.33	0.29	4.68	4.98	4.72	1.92	2.54	1.79	316	356	242

compared to control (Table 5). This was due to higher yield and higher soil nutrient status and also of higher biomass. Further, decomposition of residue resulted in higher availability of N, P and K which helped in increased uptake of nutrients. Similar results were also reported by Sharanakumar, (2008). The enhanced moisture and nutrient contribution due to added mulch material led to increased biomass production and hence higher N uptake. Similar results were also observed by Sharma *et al. (2010).*

Apparent recovery and agronomic efficiency of N and P in wheat

Apparent nitrogen and phosphorus recovery efficiency was significantly influenced due to mulching treatments. Application of mulch during both *kharif* and *rabi* recorded higher nitrogen and phosphorus recovery efficiency in 2013-14, 2014-15 and pooled analysis as compared to control (Table 6). Both seasoned mulch crops recoreded 104.72 per cent of N and 30.57 per cent of P apparent recovered (pooled data) efficiency was observed compared to with out mulch. Significantly higher agronomic efficiency of nitrogen (70.22 % pooled data) and phosphrous (14.43 % pooled data) were recorded in wheat with mulch to both maize and wheat as compared to without mulch treatments.

Effect of mulching on available moisture status

At the time of sowing, the available moisture per cent was 60.53 in *kharif* mulched plot and it was 56.33 per cent in non mulched treatment. The total stored moisture was 150.9 mm/ 0.9m in these plots. Since, the moisture content was more than 60 per cent, the germination was good. After the establishment of the crops there were no rains till harvest. So, the crop was grown completely on stored moisture. The available water started decreasing week by week till harvest. At CRI and tillering stage (48th and 49th standard week) the available moisture was 44.87 and 49.13 per cent in both season mulched treatment and it was 41.97 and 47.96 per cent (at 0-15 and 15-30 cm depth, respectively) in non mulch treatment. These are the most important critical stages (CRI and tillering) in wheat where, the available soil moisture was less than 50 per cent. Because of this situation the number of tillers per meter row length decreased drastically (Table 1). At the time of boot leaf stage (50th standard week) (Fig 1 and 2) the available moisture was as low as, 38.14 and 38.96 per cent at 0-15 and 15-30 cm depth in both season mulch plot as compared to 32.08 and 35.18 per cent in non mulch plot. (62 per cent moisture depleted at this critical stage and the yield reduced drastically). Even at anthesis, milking stage (2nd and 3rd standard week) 17.71 and 20.36 per cent of moisture was there in mulch plot. However, it was 14.67 and 16.88 per cent in top layers of non mulch plot in top layers (0-15 and 15-30 cm). This amount of moisture helped the crop to record the yield of 1291 kg ha^{-1} as compared to 753 kg ha^{-1}. There was 43.23 per cent higher yield in mulch plot as compared to without mulch plot. However, the situation was different in 2014, the percentage moisture was 70.08 and 69.93 in both season mulch plot at 0-15 and 15-30 cm depth. Whereas, it was 59.75 and 58.49 per cent in non mulch plot. After one week of sowing (crop sown of 6th November. 2014) 14th and 15th Nov 25.4 and 23.2 mm of rains were received which increased the moisture availability from 70.08 to 90 per cent in 0-15 and 15-30 cm depth layers in mulched plot and 82.50 and 82.67 per cent in non mulched plot, respectively (Table 1 and 2) (Fig. 2). Moisture at this stage helped for good vegetative growth *viz.,* crown root initiation (CRI), tillering and jointing stage, which are the most important critical stage in wheat crop. Further at 50th std week, 26.2 mm of rains were received which increased the availability of moisture to 84.67 and 84.21 per cent in top 0-15 and 15-30 cm layers, which coincided with important critical stages *viz.,* boot leaf and inflorescence stage of the crop. In both the season mulched plot recorded 4 to 5 per cent higher moisture (at all stages of crop growth) as compared to without mulched plot. Till this stage only 25 per cent of depletion of soil moisture in soil profile.

At other important critical stages, like anthesis, milky stage and ripening stage (2nd to 6th std week *i.e.,* from 60 to 90 days after sowing) the available moisture was 66.79 and 64.01 per cent in top layers (0-15 and 15-30 cm) in both season mulched plot as compared to non mulched plot (57.11 and 57.69 %, respectively) at 2nd Std week (90 DAS) and at ripening stage, the moisture was 24.16 and 22.22 per cent in both season mulched plot. (The stored moisture was 90.92 mm/0.9 m) So, the performance of crop was good as compared to 2013. Where, 2166 kg ha^{-1} of wheat grain was harvested as compared to only 1291 kg ha^{-1} during 2013 in both season mulched plot (Table 2).

The effect of mulching was more pronounced during 2013-14 in both season mulched crop. The per cent increase was 71.44 (538 kg ha^{-1}) over non mulched crop and 27.44 per cent (278 kg ha^{-1}) over only *kharif* season mulch. Application of

Table 5. Nutrient uptake (kg/ha) at harvest in wheat as influenced by mulching practices

Treatments	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Maize fb wheat without mulch (control)	58.48	134.20	96.34	7.11	12.86	19.99	46.79	119.31	83.05
Kharif maize grown with mulch fb wheat without *kharif* mulch in *rabi*	83.95	144.44	114.19	10.49	14.55	12.52	66.78	125.54	96.16
Kharif maize without mulch fb wheat with *kharif* mulch	98.19	164.74	131.46	12.46	17.60	15.03	75.19	137.38	106.29
Kharif maize grown with mulch fb wheat with *kharif* mulch	107.93	189.47	148.70	13.55	21.71	17.63	81.54	155.67	118.61
S.Em±	3.64	4.66	3.19	0.49	0.77	0.45	3.68	4.21	2.90
C.D. (P = 0.05)	12.59	16.13	11.05	1.68	2.66	1.57	12.74	14.56	10.05

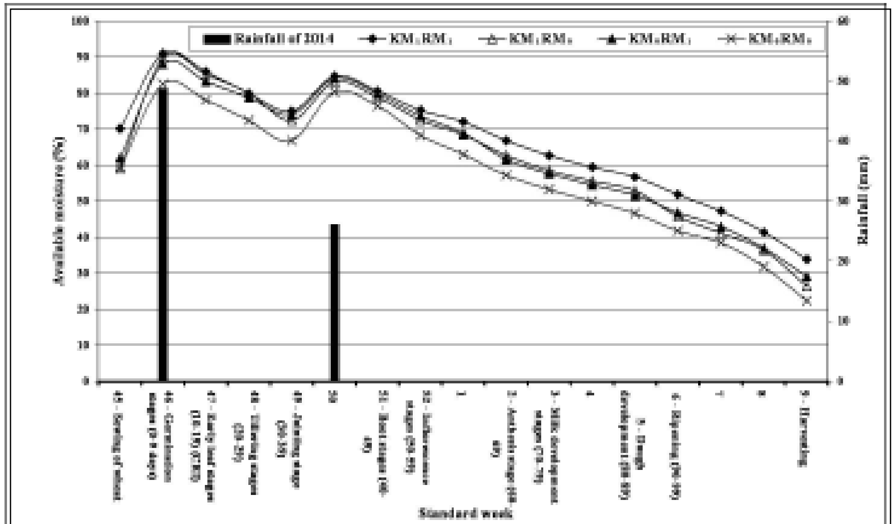

Fig. 3: Effect of mulching on available moisture in wheat crop during 2014-15 at 0-15 cm depth

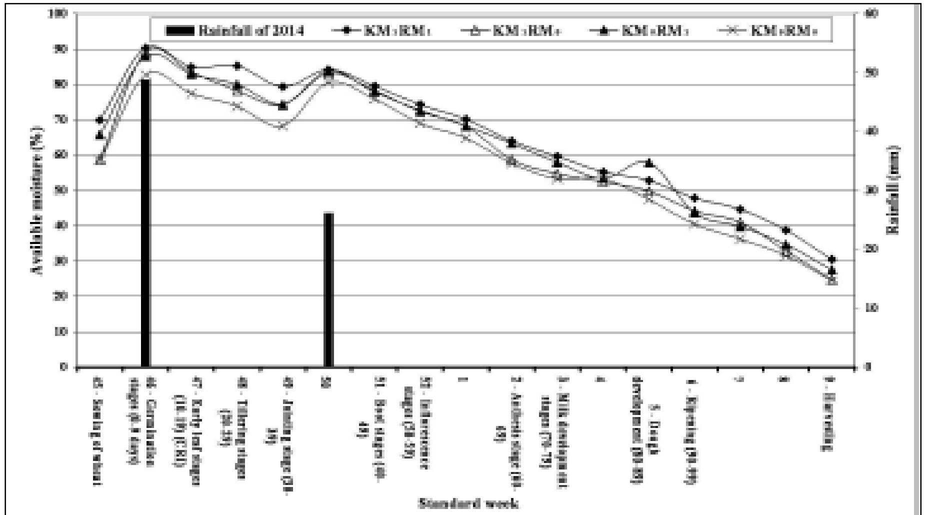

Fig. 4: Effect of mulching on available moisture in wheat crop during 2014-15 at 15-30 cm depth

Table 6. Effect of mulching practices on apparent recovery efficiency and agronomic efficiency of N and P in wheat as influenced by mulching practices

Treatment	Nitrogen						Phosphorus					
	Apparent recovery efficiency (%)			Agronomic efficiency (kg/ha)			Apparent recovery efficiency (%)			Agronomic efficiency (kg/ha)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Maize fb wheat without mulch (control)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kharif maize grown with mulch fb wheat without *kharif* mulch in *rabi*	50.93	20.47	35.70	0.93	2.47	1.70	13.55	6.73	10.14	1.87	4.93	3.40
Kharif maize without mulch fb wheat with *kharif* mulch	79.42	61.07	70.25	4.17	5.23	4.70	21.41	18.96	20.19	8.33	10.47	9.40
Kharif maize grown with mulch fb wheat with *kharif* mulch	98.90	110.53	104.72	5.67	8.77	7.22	25.77	35.37	30.57	11.37	17.50	14.43
S.Em±	7.28	9.32	6.38	0.82	1.44	0.86	1.95	3.07	1.82	1.67	2.89	1.74
C.D. at 5%	25.19	32.25	22.09	2.85	4.98	2.97	6.74	10.62	6.29	5.78	10.00	6.02

Table 7. Economics of wheat as influenced by mulching practices

Treatments	Gross returns (₹/ha)			Net returns (₹/ha)			B:C ratio		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
* Maize fb wheat without mulch (control)	12053	26357	19205	-581	12516	5968	0.96	1.90	1.43
# *Kharif* maize grown with mulch fb wheat without *kharif* mulch in *rabi*	16208	28228	22218	3574	14387	8980	1.28	2.04	1.66
Kharif maize without mulch fb wheat with *kharif* mulch	19435	30353	24894	5560	14244	9902	1.40	1.88	1.64
Kharif maize grown with mulch fb wheat with *kharif* mulch	20651	33037	26844	6776	16928	11852	1.49	2.05	1.77
S.Em±	889	1098	804	889	1098	804	0.07	0.07	0.06
C.D. at 5%	3077	3801	2784	3077	NS	2784	0.24	NS	0.20

*- Cost of cultivation- ₹12634/ha (2013-14) *- Cost of cultivation - ₹13841/ha (2014-15)

- Cost of cultivation- ₹13875/ha (2013-14) # - Cost of cultivation - ₹16109/ha (2014-15)

mulch only during *rabi* season was recorded on par with both season mulch. The mulch done only during *rabi* season also increased the yield to the tune of 462 kg ha^{-1} (61.35%) during 2013. During 2014-15, 20.22 per cent increased yields were observed over non mulched plot. This indicates that, mulch is good agronomic practice in rainfed agriculture where the farmers can get more than 20 per cent higher yields during in good rainfall situations and up to 43 per cent in bad years over non mulched treatments.

Economics of mulching in wheat

The economic analysis also revealed that the maximum benefits could be obtained from both season mulch as compared to without mulch treatment or muclh to either of the crops (₹ 74,021+ 11,852 from maize + wheat system where as, ₹ 62,036+ 5968 from same system with out mulch. *i.e.,* with an additional benefit of ₹17,869 (Table 7). Benefit: cost ratio was highest in both season mulch was lowest in without mulch treatment.Similar results were repored by Sharma *et al.* (2011a, 2011b) and Ramesh (2013).

On the basis of this two year study it may be concluded that mulch is good agronomic practice in rainfed agriculture where the farmers can get more than 20 per cent higher yields during in good rainfall situations and up to 43 per cent in bad years over non mulched treatments. Apart from this higher nutrient use efficiency, moneteray returns can be obtained.

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