Evaluation of different locally available mulching materials *vis a vis* plastic on the basis of their impact on soil properties , crop yield and water use efficiency of Rajmash (*Phaseolus vulgaris*) under different irrigation levels

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Abstract

A field experiment on a newly introduced demanding pulse crop, Rajmash(*Phaseolus vulgaris*) was conducted during two consecutive winter seasons of 2007-08 and 2008-09 in the Central Farm of Regional Research and Technology Transfer Station(RRTTS) of Orissa University of Agriculture and Technology(OUAT) at Chiplima in Sambalpur district of Odisha in India on a moderately well drained sandy loam soil in order to study the impact of three different mulching materials viz; two organic mulches, paddy straw, and sugarcane trash applied @3t ha^{-1} and the third a 50 micron black plastic at three different water management options of providing irrigation at 30, 40 and 50% depletion of available soil moisture(DASM)) on some important crop production related soil properties, availability of three primary nutrients N, P and K , grain yield. and water use efficiency(WUE). The study revealed that in both the years when averaged over the irrigation levels, paddy straw mulch caused highest increase in yield with a mean increase of 66.7% over the un mulched control treatment followed by plastic (51.9%) and sugarcane trash (11.6%). When averaged over the mulching treatments the three irrigation

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treatments were at par in influencing the yields in both the years. Among the mulching materials paddy straw which is the most common crop residue left in the field after harvest of kharif rice (June-November) created a most favourable soil environment measured in terms of bulk density, porosity, pH, organic carbon (SOC), available N, P and K and microbial respiration and enzyme urease, phosphatase and dehydrogenase followed by plastic mulch. Sugarcane trash was most inefficient in its effect on increasing grain yield and maintaining soil fertility. All the three irrigation treatments were at par in influencing the soil properties. When considered on the basis of favourable effect on soil properties and maintenance of soil fertility and crop yield, paddy straw which is available plentily in situ in the region is suggested to be used as a suitable mulching material for winter Rajmash crop for boosting the yield in water deficient areas of Sambalpur district which has a large acreage under rice.

Key words: Rajmash, mulch, irrigation, grain yield, water use efficiency, soil properties

1. Introduction

Rajmash or French bean (*Phaseolus vulgaris*) which is a rich source of protein is a newly introduced winter season (Rabi) pulse crop in Sambalpur district (20° 21' N latitude and 80° 55' E longitude) of Western Odisha, a state in eastern India. This crop has a growing demand in the region as a popular dish (Tadka) is prepared from it. To meet the increased local demand more area needs to be covered under this crop. However, there are some limitations for expansion of area under this crop. It is mostly grown in the medium lands at a wider row to row spacing of 45 cm which is favourable for weed flora to come up in a large scale and therefore the crop has to compete with weeds for its growth. Further due to high day temperature (27^0 to 34°C) and low relative humidity (50 to 56%) during crop growth period there is high evaporative and transpiration loss of water especially through weeds. Rice-rice is the major cropping system of the region and canal supply of irrigation water is largely scheduled to meet the water requirement of rice-rice system and it does not match the phasic water requirement of Rajmash crop. Therefore the crop has to be grown under deficit water supply. Thus deficit moisture and weed infestation hold the key for successful production of rajmash.

Mulching is an established technique for increasing crop yield (Duranti and Cuocolo, 1989; Gimanez *et al.,* 2002) in different crops due to its capacity to conserve soil moisture (Vavring and Roka, 2002) and increase early soil temperature (Shaw, 1959) which may influence soil properties especially of surface layer. Mulching conserves water by checking evaporation and transpiration by weeds and also modifies soil temperature and influences soil environment especially biological (Li Feng- Min *et al.* 2004).Very little weed growth occurs under the mulches. The mulches prevent penetration of light or exclude certain wavelengths of light. The effects however, vary with the type of mulch, soil and climatic conditions under which the crop is grown. Rice and sugarcane are two most important common crops extensively grown in the region where the farmers traditionally either remove the paddy straw from field for cattle feed or burn the residues of both the crops *in situ* before planting of the next crop to facilitate the tillage operation. Burning causes loss of nutrients to the tune of 80% of N(Raison,1979) 25% of P and 21% of K(Ponnamperuma,1984) and 4-60% of S(Lefroy *et al.* 1994) and soil organic matter and negatively contributes to carbon sequestration. Use of these residues as mulching materials in Rajmash will get rid of these twin problems and help the crop to grow under deficit irrigation with reduced weed problem. For optimum crop growth with profitable cultivation the practice of mulching and irrigation needs to be standardized. Therefore the study was conducted to evaluate paddy straw and sugarcane trash *vis -a- vis* plastic film as mulching materials with respect to their effect on some selected soil properties important from nutrient cycling point of view and crop yield of Rajmash under different irrigation schedules.

2. Materials and Methods

A field experiment on Rajmash (*Phaseolus vulgaris*) was conducted during winter seasons of 2007-08 and 2008-09 on a moderately well drained medium land of the Central Research Farm at the Chiplima Centre of Regional Research and Technology Transfer Station (RRTTS) of Orissa University of Agriculture and Technology (OUAT), Sambalpur district about 360 kms away from the state capital of Bhubaneswar. Mean annual rainfall at the experimental site is 1459mm with average maximum temperature of 40.20C (May) and minimum of 12.5^{0}C (December).

The soil of the experimental site is a sandy loam composed of 74.38% sand, 12.56%silt and 13.06 % clay with acidic reaction (pH 5.78).The soil contained 0.78% organic carbon,1440 kg/ha of total nitrogen(Kjeldahl method)), 34kg ha^{-1}of available Phosphorous(Bray's-1) and 122 kg/ha of available potassium(Ammonium acetate extraction). The experiment consisted of three irrigation schedules such as irrigation at 30%, 50% and 60% depletion of available soil moisture (ASM) taken as main plot treatments and three mulching treatments such as sugarcane trash, paddy straw and plastic and an un mulched control taken in subplots. The experiment with twelve treatments was laid out in a split plot design with 3 replications.

2.1 Land preparation and planting

Following harvest of a medium duration (120days) kharif rice, the land was ploughed three times , leveled and Rajmash (cv:*Chitra in 2007-08 and cv; Contender in 2008-09*) seeds were sown in narrow and shallow furrows in the month of November with row to row spacing of 45 cm and plant to plant spacing of 10 cm in plots of dimension 6m × 5m in both the years with rice as kharif crop (July-October). Uniform dose of FYM @ 2t ha^{-1} and fertilizer NPK(100-60-40) was applied through urea, DAP and MOP in both the years Half dose of N and full doses of P and K were applied at sowing and rest 50% N was top dressed at 20 days after sowing.

2.2 Mulching and Irrigation

The mulching treatments were imposed at 20DAS when first intercultural operation was undertaken. Black plastic films of 50μ thickness and 45 cm width were placed between the rows and paddy straw and sugarcane trash mulching was done on the same day @3t ha^{-1} by uniformly spreading over the surface as a carpet manually. The straw contained 48.7% C, 0.6% N, 0.22%P,1.2% K with C/N of 81.2; where as the sugarcane trash contained 51.2% C,0.42% N,0.18% P,0.72% K with C/N of 122.The Lignin content in sugarcane trash was more than that of paddy straw. After mulching one common irrigation of 6 cm was given to all the treatments and further irrigations were applied as per the respective main plot treatments.

2.3 Biomass of Weed and Crop yield

Weeds were removed from two different $1m^2$ areas of each field at 60 DAT, oven dried after air drying for 2days and dry weight of the biomass was measured in terms of g m^{-2} by averaging the two locations in each plot.

An area of 1.8m x 1m (for 4rows of 1m length) was marked by fixing 4 number of sticks at the centre of each plot that included 4rows of 1m length which was left undisturbed until final harvest. Plants were cut from soil surface and pods were separated .All the samples were air dried and seeds were separated and air dry weights of seeds were recorded.

2.4 Soil sampling and Laboratory analysis

.Surface (0-15cm) soil samples collected after the harvest of second year rajmash crop were analysed after air drying for various soil properties such as pH(soil : water of 1:2 ratio), organic carbon (Walkley Black's rapid titration method), available N(Alkaline $KMnO_4$ method), available P(Bray's-1 extractable) and available K (Ammonium acetate extractable). Soil bulk density was determined by gravimetric method for which soil was sampled through manual coring up to 5 cm depth. For knowing the effect on biological properties, microbial respiration (Pelczar *et al*. 1993) and enzyme activities such as dehydrogenase (Casida *et al.*1964), urease (Tabatabai 1982) and acid phosphatase (Dick *et al.* 1996) were determined on air dried soil samples. Water use efficiency (WUE) was calculated from the yield and WR for each treatment.

2.5 Statistical Analysis

The results on crop yield, soil physical, chemical and microbiological parameters were then subjected to analysis of the variance (ANOVA) using least significant difference (LSD) test for comparing treatment effects on various parameters (Gomez and Gomez 1984).

3. Results and Discussion

3.1 Soil Properties

Soil samples collected immediately after harvest of the second crop were processed and analyzed for assessing changes in bulk density (BD), pH, soil organic carbon (SOC), available NPK, microbial respiration, activities of enzyme dehydrogenase, urease and phosphatase and the results were recorded in table 1 and 2.

3.1.1 Bulk Density (BD)

Within two years of continuous cropping neither the mulching nor the irrigation treatment had any significant effect on soil bulk density. When averaged over the irrigation treatment, lowest BD of 1.32 Mg m^{-3} was observed with paddy straw followed by 1.39 Mg $m^{-3}$with sugarcane trash,1.44 Mg m^{-3} in plastic mulch and highest of 1.46 Mg m^{-3} in the un mulched treatment as compared to the initial 1.40 Mg m^{-3}. When averaged over the mulching treatments the BD values measured 1.34, 1.36 and 1.44 Mg m^{-3} at 30, 40 and 60% depletion of soil moisture (DASM) respectively. With respect to porosity among mulched treatments lowest(42.50%) in plastic mulch as compared to 48.03% in paddy straw, 45.27% in sugarcane trash mulch. The unmulched soil also had low BD (42.17%). Khurshid *et al.,* (2006) and Glab and Kulig (2008) reported that mulching increased soil porosity and reduced soil compaction. In a study made earlier Thompson (1966) had however, showed no significant effect of sugarcane mulch on soil bulk density and porosity. Thus from the results of the present study it may be concluded that paddy straw is more effective than sugarcane trash and plastic mulch.

3.1.2 Soil pH

Within two years, there was significant increase in soil pH in organically mulched treatments. The pH increased from initial 5.78 to 5.98 with sugarcane trash and 5.78 to 6.09 with paddy straw. Increased pH in organically mulched soil has also been reported by Borthakur and

Bhattacharya (1992) and Shashidhar *et al*., (2009). This increase is attributed to liberation of base during the process of decay of the organic mulches (Shashidhar *et al.* (2009). In contrast, the pH remained unchanged (5.78) with plastic mulch. This also corroborated the above fact as plastic mulch had no decomposition effect. Irrigation at 50and 60% DASM also recorded significantly higher soil pH of 6.03 and 6.01 respectively than that at 30% DASM(5.79).This might be due to greater decomposition effect with less frequent irrigation and less leaching of bases.

3.1.3 Soil Organic Carbon (SOC)

Treatment with organic mulching maintained a higher level of organic carbon (0.74-0.79%) than the plastic mulch (0.70%) and unmulched treatment (0.68%). Between the two organic mulches higher value of 0.79% was recorded with paddy straw mulch which was 16.2% higher than the unmulched treatment when averaged over the irrigation levels. This is in agreement with results of Li Peng *et al,* (2004) who reported a decrease in soil organic carbon with plastic film and unmulched treatment. Irrigation treatments also significantly influenced the soil organic carbon. Irrigation at 30% DASM maintained highest SOC of 0.77% followed by 0.74% at 50% DASM and 0.67% at 60% DASM.This supported the result that at 50 and 60% DASM there is greater decomposition and more loss of carbon than that at more frequent irrigation with 30% DASM..

3.1.4 Available Nutrients

Results on soil available nitrogen, phosphorus and potassium showed that among the three types of mulching materials, paddy straw mulch recorded highest level of all the three primary nutrients.

3.1.4.1 Available Nitrogen (N)

With two years of mulching with paddy straw the available N content increased from the initial value of 248kg $ha^{-1}$to 307kg ha^{-1}. The increase was significantly higher than that with plastic mulch (272kg ha^{-1}) and no mulch (273kg ha^{-1}). Sugarcane trash with 285kg N $ha^{-1}$was however, at par with paddy straw. This might be due to the release of more N caused by decomposition and mineralization of both the organic materials which respectively contributed about 20kg and 15kg of total N/ha in one year in contrast to plastic mulch that did not add any N directly. Unlike the mulching treatments the irrigation treatments did not show any significant effect on available N content after two years of continuous cropping.

3.1.4.2 Available Phosphorus (P)

Unlike N availability that mostly depended on soil organic matter, availability of P depended both on organic matter mineralization and release from clay minerals through various mechanisms. Therefore its behavior is different from that of N in a soil system. Like N, highest mean available P of 37.60kg $ha^{-1}$was also recorded with paddy straw mulch. But unlike N it was significantly higher than both sugarcane trash (34.23kg ha^{-1}) and plastic mulch (34.46kg ha^{-1}) and no mulch (32.79kg ha^{-1}).Higher available P with paddy straw might be due to greater P addition through it and higher microbial activity. From the results however, it is clear that mulching increases the available P which might be due to the effect of mulching on soil temperature and moisture and creation of a favourable environment. Mulching significantly increases the soil temperature and moisture and the increase in temperature is more with black plastic than straw (Truax and Gagnon 1993). Like N, available P was not significantly influenced by the irrigation treatments. From the results however it is clear that with more frequent irrigation at the end of crop season less phosphorus was maintained.

3.1.4.3 Available Potassium (K)

In soil available K depends on all forms of K viz; mineral, fixed, exchangeable and solution K those are in dynamic equilibrium with one another. Addition of K either through fertilizer or through organic matter and other soil, plant and climatic factors also influence its availability. Organic mulches contribute to soil K through addition of K contained in them and indirectly through their effect on soil environment such as soil temperature and moisture. Among the mulched treatments paddy straw that contributed around 30kg K ha^{-1} to the soil recorded highest amount of available K (118kg ha^{-1}) .Plastic mulch that contained no K also maintained statistically same amount of K (115kg ha^{-1}) which might be due to creation of a favourable environment by increase of temperature (Sparks and Liebhardt, 1982) and moisture (Nye, 1966) releasing more K from soil. This is in agreement with the result reported by Truax and Gagnon (1993) that average soil K was higher under plastic mulch than no mulch and other organic mulches like paper and pine mulch. Available K (103kg ha^{-1}) with sugarcane trash was significantly lower than paddy straw mulch and plastic mulch and was at par with no mulch (97kg ha^{-1}). Similar to N and P, available K was also not influenced by the irrigation treatments.

3.1.5 Biological Properties

Results on effect of mulching and irrigation levels on soil microbial properties recorded in table 3 reveal that two years of mulching had significant positive effect on soil respiration, and activities of enzymes urease, phosphatase and dehydrogenase. In contrast to the effect on physical and chemical properties of soil as discussed above, paddy straw mulch and plastic mulch were equally efficient in improving the soil biological activity. Among the mulching treatments sugarcane trash had minimum effect and was almost at par with unmulched treatment with respect to their effect on respiration and phosphatase activity.

3.1.5.1 Soil Respiration

Highest mean soil respiration of 0.274mg CO_2 g^{-1} soil per day was observed with paddy straw mulch which was at par with plastic mulch (0.273mg) and 25.68% higher than no mulch (0.218mg). Sugarcane trash mulch (0.220mg CO_2 g^{-1} soil per day) which was at par with no mulch was most inefficient among the three mulching materials used in maintaining soil microbial respiration. Similar observations were also made with respect to three enzyme activities urease, phosphatase and dehydrogenase with the order paddy straw = plastic mulch > sugarcane trash > no mulch. The three irrigation treatments also were at par in their influence on the soil microbial properties studied. Thus because of maintenance of favourable soil physical, chemical and biological condition the nutrient availability was better with paddy straw mulch. This might be the reason why paddy straw mulch produced highest yield in both the years.

3.1.5.2Urease activity

Results on mean urease activity revealed that all mulched soils maintained significantly higher urease activity than the unmulched soil (78.7mg NH_4^+kg $^{-1}$soil per 2hrs). Both paddy straw and plastic mulch recorded the same (110mg NH_4^+kg $^{-1}$soil per 2hrs) mean activity which was significantly higher than that with sugarcane trash mulch(89.5110mg $NH_4^{+/}$kg $^{-1}$soil per 2hrs).All the three irrigation treatments did not significantly differ in their influence on urease. With same urease activity the soil under paddy straw mulch however maintained a higher level of alkaline $KMnO_4$ (mineralisable) than plastic mulch. This might be due to maintenance of higher organic matter in soil under 3t/ha of paddy straw mulch that decomposed during crop growing period resulting in more available N. The soil under sugarcane trash also had higher available N (285kg ha^{-1}) than the soil under plastic (273kg ha^{-1}) because of the same reason. Some authors suggested that enzyme activities were closely correlated to the total amount of carbon and nitrogen (Kheyrodin and Antoun, 2008).

3.1.5.3 Phosphatase activity

When averaged over the three irrigation treatments phosphatase activity varied from a lowest of 108mg p-nitrophenol found in the un-mulched control to 140mg p-nitrophenol kg^{-1} soil per hr found in soil under paddy straw mulch. Plastic mulch with 136mg activity was at par with straw mulch, but significantly higher than that with sugarcane mulch (117mg p-nitrophenol kg^{-1} soil per hr). Unlike urease, sugarcane trash mulch did not have any significant effect on this enzyme. However with respect to available P both sugarcane mulch and plastic mulch were at par and recorded 4-5% more P than un-mulched control. Paddy straw mulch with higher organic matter and highest phosphatase activity recorded highest available P in soil. Like urease activity the irrigation treatments were also at par in their influence on phosphatase activity.

3.1.5.4 Dehydrogenase activity

The mean value data on enzyme dehydrogenase showed that all the three mulched soils recorded significantly higher dehydrogenase activity than the unmulched control. Among the mulched treatments, paddy straw recorded highest activity of 251mg TPF kg^{-1} soil per 24hrs followed by plastic mulch with 247mg and sugarcane trash with 195mg. Irrigation treatments also did not differ in their influence on enzyme dehydrogenase.Thus mulching treatments were in the order :paddy straw = plastic mulch > sugarcane trash > no mulch with respect to their influence on soil microbial activity.

3.2 Weed Infestation

Weed infestation was studied by measuring dry weight of weeds per sq m at 60DAS of the crop grown during 2008-09. The mulching treatments differed significantly in weed infestation. The plastic mulch recorded the lowest biomass (15g m^{-2}) whereas the unmulched treatment gave highest biomass of 72g m^{-2}.Paddy straw mulch measured 32g m^{-2} as compared to 48g m^{-2} in sugarcane trash mulch signifying the sugarcane trash mulch to be ineffective in weed suppression (plate-1). Plastic mulch and paddy straw mulch were effective in control of weeds which is in agreement with the results of Ramakrishna *et al*.(2006) who worked on groundnut.

3.3 Crop yield

Results on effect of mulching and irrigation levels on grain yield of Rajmash (table 3) reveal that during 2007-08, grain yield of Rajmash (cv, *Chitra*) varied from 5.00 to 8.33 q ha^{-1} and was significantly influenced by the mulching treatments but not by different levels of irrigation. When averaged over the irrigation treatments paddy straw mulch produced highest yield of 7.26 q ha^{-1} which was significantly higher than the yields obtained in all other mulching treatments. During 2008-09 irrigation schedules like previous year, also had no significant effect and paddy straw mulch also produced highest yield of 13.69 q ha^{-1} which was however at par with plastic mulch (12.78 q ha^{-1}) and significantly superior to sugarcane trash (7.65q ha^{-1}) and no mulch (6.56q ha^{-1}) treatments. In contrast, Mahajan *et al.* (2007) had reported that black plastic was superior to rice straw mulch in increasing the yield of baby corn and field corn respectively. The yields of both the years when pooled were in the order: paddy straw mulch = plastic mulch > sugarcane mulch = no mulch. The results of two years thus showed that both paddy straw mulch and plastic mulch were almost at par but significantly superior to sugarcane mulch in influencing the grain yield. Thus sugarcane trash mulch with minimum effect was in no way different from the unmulched treatment. This might be due to the phyto-toxic effect of sugarcane trash leachate that contained phenolic acids such as vanilic acid, ferulic acid and syringic acid (Samprieto *et al*.,2005).Because of heavy amount of trash(3t ha^{-1}) added to the soil for mulching the phenolic acid concentration becomes high enough to inhibit the growth of young plants. These compounds can be leached from plant straws into soil (Souto *et al*.2001).This might also be due to more weed infestation and less nutrient availability. On the other hand, when averaged over the mulching treatments, irrigation at 30% depletion of ASM in 2007-08 and 2008-09 produced highest yields of 6.25 and 10.98q ha^{-1} respectively which however, were at par with irrigation at 50% and 60% depletion of ASM.

3.4 Water Use Efficiency (WUE)

Water use efficiency was derived from the crop yield and water requirement in different treatments in both the years. It varied from 20.67 to 29.66 kg $ha\text{-}cm^{-1}$ during 2007-08 and 28.21 to 57.06 kg $ha\text{-}cm^{-1}$ during 2008-09(table 3). Higher WUE measured during 2008-09 is due to higher yield at same level of water requirement. As evident from table 3, paddy straw mulch recorded maximum yield and highest WUE in both the years and the mean water use efficiency of two years was 37.68 kg $ha\text{-}cm^{-1}$ as compared to 33.87 kg $ha\text{-}cm^{-1}$ with plastic mulch. Lowest WUE of 26.81 kg $ha\text{-}cm^{-1}$ was recorded in un-mulched plots. With respect to WUE the irrigation treatments varied to a smaller extent and they were in the order 30% >50% >60%DASM.

Although total requirement of water at 60% DASM was more than that at 30% DASM, three numbers of less irrigation were required with the former as compared to the latter. Considering insignificant yield difference and reduced number of irrigation requirement , applying water at 60% DASM is suggested for winter rajmash grown under inter row mulching with paddy straw which is abundantly and easily available *in situ* as kharif rice grown in the same field is machine harvested leaving behind 3tonnes of paddy straw/ha. Inter row mulching with paddy straw provided a favourable soil environment with reduced weed growth, improved soil structure and higher status of nutrients .

3.5 Interaction Effect

Interaction effect of mulching treatments and irrigation levels was found to be non significant(Fig.1).The mean data of two year study revealed that the grain yield at all the three irrigation levels of 30%, 50% and 60% DASM in all the mulching treatments are statistically same. Further the study indicated that paddy straw mulch and plastic mulch even with less frequent irrigation (60%DASM) gave statistically higher yield than that with sugarcane trash mulch and no mulch with more frequent irrigation (30%DASM). This was perhaps due to better conservation of moisture and control of weeds (Mahajan *et al.* 2007)

4.0 Conclusion

Higher yield of rajmash (*Phaseolus vulgais*) can be obtained by mulching the soil with paddy straw at 20 days after sowing. Plastic mulch was also at par with paddy straw mulch and sugarcane mulching was most inefficient. As paddy is the dominant crop of the zone, availability of paddy straw is not a constraint. Crop yield with providing irrigation at 60% depletion of ASM was at par with that at 30% depletion and paddy straw mulch created more favourable soil conditions than other mulched and unmulched treatments by improving soil porosity, SOC, available nutrients and microbial activity measured in terms of urease, phosphatase and dehydrogenase. So inter row mulching of Rajmash crop with paddy straw @ 3 t ha^{-1} with irrigation at 60% depletion of soil moisture can be adopted as a practice in successfully growing the crop in water deficit areas of Hirakud command of Odisha.

5.0 Future Research

Future research however needs to be done to grow the crop with minimum tillage simply by dribbling the seeds into the soil with proper spacing as paddy straws after harvest are left on the field. This will save the cost on land preparation and spreading of straw.

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Table 1. Effect of mulching and Irrigation treatments on changes in some selective physical and chemical properties of surface soil after two years of Rajmash cultivation

Treatments	BD (Mg m^{-3}	pH	SOC(%)	Alkaline $KMnO_4$- N ($kg\ ha^{-1}$)	Bray'sP ($kg\ ha^{-1}$)	NH_4OAc-K ($kg\ ha^{-1}$)
Effect of mulching treatments						
Sugarcane trash	1.39	5.98	0.74	285	34.23	103.33
Paddy straw	1.32	6.09	0.79	307	37.60	118.33
Plastic	1.46	5.78	0.70	272	34.46	115.56
No mulch	1.47	5.92	0.68	273	32.79	97.11
*P<0.05	NS	0.149	0.039	27	2.660	12.59
Effect of irrigation treatments						
30% DASM	1.34	5.79	0.77	283	33.29	110.00
50% DASM	1.36	6.03	0.74	292	35.55	109.08
60% DASM	1.44	6.01	0.67	277	35.47	106.67
*P<0.05	NS	0.132	0.038	NS	NS	NS
Initial	1.40	5.78	0.78	248	34.00	122.00

NS- Non significant , DASM- Depletion of available soil moisture

Table 2. Effect of mulching and Irrigation treatments on changes in microbial properties of surface soil after two years of Rajmash cultivation

Treatments	**Soil Respiration (mg CO_2 g^{-1}soil day $^{-1}$)**	**Urease Activity (mg NH_4^+ kg $^{-1}$soil 2h $^{-1}$)**	**Phosphatase activity (mg p nitrophenol kg ^{1}soil h $^{-1}$)**	**Dehydrogenase Activity (mg TPF kg-^{1} soil per 24hrs)**
Effect of mulching treatments				
Sugarcane trash	0.220	89.51	117	195
Paddy straw	0.274	110.60	140	251
Plastic	0.273	110.15	136	247
No mulch	0.218	78.73	108	157
*P<0.05	0.043	9.75	17	38
Effect of irrigation treatments				
30% DASM	0.235	94.69	121	219
50% DASM	0.264	99.48	133	230
60% DASM	0.242	97.58	122	188
*P<0.05	NS	NS	NS	NS
Initial	0.186	68.56	87	147

NS- Non significant , DASM- Depletion of available soil moisture

Table 3. Effect of mulching and Irrigation treatments on Rajmash (*Phaseolus vulgaris*) yield, water requirement andwater use efficiency

Treat	Seed yield (q ha^{-1})			Water requirement(cm)			Water use efficiency (kg $ha\text{-}cm^{-1}$)		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Effect of mulching treatments									
Sugarcane trash	6.37	7.65	7.01	28.29	27.34	27.82	22.50	38.64	30.57
Paddy straw	7.26	13.69	10.47	27.27	27.02	27.15	26.77	48.59	37.68
Plastic	6.30	12.78	9.39	27.59	27.03	27.31	22.93	44.81	33.87
No mulch	6.00	6.56	6.43	27.91	27.66	27.79	22.27	31.35	26.81
*P<0.05	0. 83	3.01	1.92						
Effect of irrigation treatments									
30% DASM	6.25	10.98	8.62	24.89	23.28	24.14	25.16	46.18	35.67
50% DASM	6.58	9.92	8.25	29.48	29.28	29.38	22.48	39.59	31.22
60% DASM	6.61	9.62	8.12	28.92	29.14	29.03	22.86	36.76	29.81
*P<0.05	1.25	1.946	0.79						

DASM- Depletion of available soil moisture

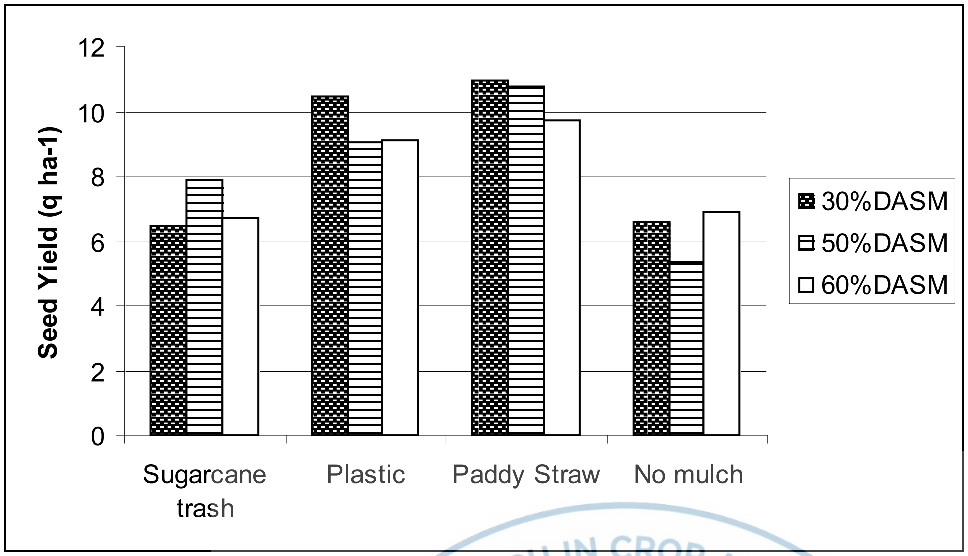

Figure 1.Interaction effect of mulching treatments and irrigation levels on grain yield of Rajmash (Mean of 2 years)

Plate No.1: Four mulching treatments of the experimental field with the Rajmash(cv: *Contender*) crop at early fruiting stage