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# Rice cultivation using plastic mulch under saturated moisture regime and its implications on weed management, water saving, productivity and profitability

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**ABSTRACT**

A *Rabi* season (2012-13) field investigation was carried out at Directorate of Rice Research, Hyderabad to assess the impact of saturated moisture regime (SMR) with and without plastic mulching (black and transparent) in transplanted rice (TPR) on weed menace, water saving, productivity and economics as compared to 5 cm standing water regime (SWR) rice in RBD with six replications. Results revealed that no-mulch SMR rice has 37.3 and 80.2% higher weed count and thus 26.8 and 114.1% lower weed control efficiency than SWR rice culture at 20 and 40 days after transplanting. Plastic mulching (PM) with SMR has reduced the weed count and weed biomass in rice by over 90% as compared to no-mulch-SWR rice. Labour days required for weeding were enhanced by 50% under SMR (30 man days) as compared SWR (20 man days). SMR had 35% irrigation water (IW) economy but with 7.1% grain yield penalty (0.34 t/ha) as compared to SWR (100 cm IW use and 4.79 t/ha grain yield). When SMR was combined with plastic mulching (PM), there was aless yield depression (0.10-0.18 t/ha) when compared to SWR. SWR has more net returns (` 42,160/ha) than SMR (` 30,750). High cost of PM (` 23,000/ha) with SMR has masked gains in IW, weeding costs saving and higher yields. SMR can be adopted without any challenges but weed management through PM is desired with added advantage of water economy. Reducing cost of plastic mulches and evolving biodegradable plastics may make SMR rice culture a reality.

Rice (*Oryza sativa* L.) is the most important staple crop of India cultivated on 43.79 mha with a production of 168.5 million tonnes of un-milled rice in 2017 (FAOSTAT 2019). About 60.1% of the rice crop's total area in 2014-15 was under irrigation (Anonymous 2017) and thus is the highest water consumer in the country with an estimated water foot print of 432.9 billion $m^3$ including percolation losses during 2000-2004 (Chapagain and Hoekstra 2011). However, over time, on account of rising population, the per capita water availability in the country has got reduced from safe limit of 1700 $m^3$ in 2001 (1820 $m^3$) to 1545 $m^3$ by 2011 and is slated to reach 1140 $m^3$ by 2030 (Sengupta 2018) and country becomes water stressed. Accordingly, the share of water for agriculture (GOI 2009) is declining from 88 (2000) to anticipated level of 72% by 2050. These reduced water supplies call for rational use of water by all sectors in general and crops like rice in particular. Post-monsoon rice accounting for 13.1% of total rice production during 2017-18 (DOES, 2018) relies heavily on conserved waters (stored and ground water). In this context, water efficient rice production technologies *i.e.* (i) saturated soil culture through system of rice intensification, alternate wetting and drying (Peng *et al.* 2006); (ii) aerobic rice culture with irrigation at critical stages (Boumann *et al.* 2002) and (iii) ground cover rice production systems (GCRPS) involving mulches (Tao *et al.* 2006) and drip irrigation (Haibing He *et al.*2013) need focussed attention. Studies have indicated the utility of GCPRS in weed management too by thermal regulation (Kasirajan and Ngouajio 2012) and physical exclusion. In India, studies pertaining to GCPRS are yet to be made. The contributions of GCPRS to weed management needs to be weighed from contributions of standing water of TPR to reduced weed pressures (Kent and Johnson 2001). Keeping the dearth of information on GCPRS to weed management, a field study was carried out during *Rabi* season of 2012-13 (December-April) to assess the utility of plastic film mulch cultivation of rice with saturation moisture regime when compared to standing water TPR culture on weed menace, crop productivity and profitability.

Field studies were conducted during *Rabi* season of December 2012- April, 2013 at Directorate of Rice Research, Rajendranagar, Hyderabad, located at $19^0$ N latitude and $74^0$E longitude at an altitude of 700 m above mean sea level.The experimental region had a semi-arid climate.A rainfall of 32.2 mm in 4 rainy days (a day with >2.5 mm rain/day) was received and mean maximum and minimum temperature during crop life (January- 20th April) was 31.9 and $16.8^0$C.The experimental clay loam soil (Vertisols; Typic Pellustert) with a 7.8 pH at the start of study in December, 2012 in its top 20 cm layer soil was collected and analysed as per Jackson (1973) contained 0.67% organic carbon and was rated low for available nitrogen (268.1kg/ha $KMnO_4$ extractable N), medium for available phosphorus (18.2 kg/ha 0.5 M $NaHCO_3$ extractable P) and potassium (379.8 kg/ ha $NH_4OAC$ extractable K). The soil with a bulk density of 1.40 g/cc had a field capacity (FC) and permanent wilting point (PWP) moisture of 23 and 13%. Four mulching and moisture regime treatments were evaluated in randomized complete block design with six replications per treatment in transplanted rice. The treatments were (i)no mulch-5 cm standing water rice (SWR), (ii) no mulch-saturation moisture rice (SMR), (iii) black polythene mulch (BPM) - SMR and (iv) transparent (TPM)-SMR. In a well prepared land by 3 times ploughing and puddling followed by levelling, present experiment was laid out. Plastic film mulches (1.4 m width, 15 m length and 25 gsm thickness) as per treatment were spread on the field with inward folding of plastic sheet into the soil and placing of wet soil on all sides to form a bund of 15 cm height with a channel following the plot of 15 m length on all sides. A wooden marker with pegs at 20 cm distance apart having 6 pegs was prepared and pressed into the PM sheets at 10 cm spacing (to maintain 20 x 10 cm planting geometry). Into these holes, twenty-five day old '*MTU-1010*' rice seedlings were manually transplanted on 30th December, 2012. Phosphorus (26.4 kg/ha P) and potassium (36 kg/ haK) fertilizers were applied through single super phosphate and muriate of potash in last puddling uniformly to all treatments. Nitrogen as prilled urea (150 kg/ha) was broadcast applied on 5, 30 and 45 days after transplanting (DAT) in unmulched rice crop. In mulched treatments, 100 kg N was applied as basal along with P and K. Remaining N was mixed with irrigation water at water delivery point of each plot at 16.7 kg/ha on 30, 40 and 50 DAT. Two manual weeding were done on 20 and 40 DAT. Weed count in 0.5 $m^2$ quadrate at two locations/plot was recorded (same quadrats data recorded each time) prior to weeding and weeds were removed along with their roots. Root portion of weeds was cut and above ground portion of weeds was oven dried at $60^0$ C for 48 hours to attain a constant weight and weight was recorded expressed as $g/m^2$. At harvest also, crop was harvested carefully leaving the weeds intact and their count and weight (above ground) was recorded as above. Weeds were not separated into grass, broad-leaved weed and sedges treatment wise. However, weed flora of SWR and SMR was enlisted separately. Weed Control Efficiency (WCE) in per cent (%) was worked out as per Ahlawat *et al.* (2005); WCE (%) = {Weed dry weight (g) in no mulch standing water rice - weed dry weight in no mulch/mulch rice- with saturation moisture/weed dry weight in no mulch standing water rice} x 100. As weed count and dry weight data have zero values, the data was subjected to square root transformation ($\sqrt{x+0.5}$) prior to statistical analysis.For manual weeding, 20,30 and 2 man days were used for SWR, SMR and PM + SMR treatments and a labour cost of ` 300/day was used for economic calculations.

Water was applied to each plot through PVC pipes of 10 cm diameter to maintain SMR in mulched treatments and SWR (5 cm) was maintained from 3 DAT onwards. Irrigation water (IW) of bore well lifted by electrical pump set was applied after measurement. Saturation moisture regime was maintained by alternate day irrigation. In SWR, water was let in whenever water depth was coming below 4 cm depth at bench mark point kept in each plot. Irrigation was stopped from 5th April onwards. Benefit-Cost (BC) ratio was worked out as ratio of gross income (net income + cost of cultivation) to cost of cultivation (`/ha). Growth was recorded in non-destructive way through recording plant height and tiller numbers in treatments (data not given).Yield attributes (data not given) from ten randomly selected hills and yield (straw and grain) from net plot (kg/ha) were recorded post-harvest. Crop was harvested at physiological maturity on 20th April. In the calculation of economics, minimum support price of rice grain (` 14,500/ tonne) and market price of straw (` 2,500/ tonne) were used. For plastic mulch treatment imposition in field, 10-man days (` 3,000) and plastic cost of ` 20,000/ha were used. Need based plant protection measures were taken for successful cultivation of crop without any yield penalties. For SMR irrigation, 7-man days were used. Economics was worked out with no cost of irrigation water. The analysis of variance (ANOVA) was done in randomized complete block design. The significance of treatment differences was compared by critical difference (CD) at 5% level of significance (p=0.05) and statistical interpretation of treatments was done as per Gomez and Gomez (1984).

Weather was highly congenial for rice cultivation. During the rice growing period, 32.2 mm rainfall was received and crop was raised on bore well water irrigation and faced no stress. The mean minimum temperatures ranged from 10.1-28.0 $^0$C and the maximum temperature from 20.0-40.0 $^0$C. Near absence of rains during study period has enabled in effective implementation of soil moisture regimes and mulching treatments and any differences in crop performance were ascribed to treatments under study only.

### Weed flora

**No mulch- standing water rice**: The weed flora of no mulch-SWR treatment at 20 and 40 DAT consisted of 15 weeds (grasses, sedges and broad-leaved weeds). Weed species (relative value index) include: *Echinochloa colona* (24.3%), *Cyperus* spp. (20.3%), *Commelina benghalensis* (10.2%), *Ammania baccifera* (8.8%) and *Scripus* (6.1%) that together accounted for 69.7% of weed counts. *Aeschynomene indica* (5.4%), *Monochoria vaginallis* (4.2%) and *Bulbostylis barbata* (3.7%) were the other important weeds that accounted for 13.3% of total weed count. Rest 17% weed count was accounted by other 7 weeds *Fimbristylis miliaceae Alternanthera sessilis, Caesulia axillaris, Eclipta alba, Ludwigia parviflora, Marselia quadrifolia* and *Sphenoclea zeylanica.*

**No mulch-saturation moisture rice**: The weed flora of no mulch-SMR treatment was 1.3 times more diverse (20 weed species) than SWR rice. Weed species (relative value index) include: *Cyperus* spp. (21.5%), *E. colona* (19.8%), *C. benghalensis* (8.9%), *A. baccifera* (6.5%) and *Scripus* (4.9%) that together accounted for 61.6% of weed counts. *A. indica* (4.9%), *M. vaginallis* (1.5%) and *B. barbata* (2.0) were the other important weeds that accounted for 8.4% of weed count. Rest 30% weed count was accounted by other 11 weeds *i.e. F. miliaceae, A. sessilis, C. axillaris, E. alba, L. parviflora, M. quadrifolia* and *S. zeylanica, D. sanguinalis. D. retroflexa, D. aegyptium, L. chinensis* and *E. crus-galli*.

**Plastic mulch-saturation moisture rice**: The weed flora of plastic mulch- SMR was confined to 3-5 grassy weeds only. These weeds looking similar to rice might have been transplanted along with rice seedlings. *E. colona* (40.8%), *Cyperus* spp. (38.5%), *F. miliaceae* (10.9%), *E. indica* (6.5%) and *D. sanguinalis* (3.3%).

### Weed count and weed biomass

Weed count and weed biomass of transplanted rice varied greatly among mulching and moisture regimes (**Table 1**). Plastic mulching almost excluded the weed pressure on rice crop irrespective of its colour (black/transparent) by acting as physical barrier between emerging weeds and sun light. Weeds that germinated below the mulch died quickly on account of lack of sunlight for photosynthesis. Only the weeds emerged from within the rice hill from the holes of plastic survived and that were very few. Thus a weed count reduction of 91, 90.5 and 100% at 20, 40 DAT and at harvest stages have effected a concomitant reduction in weed biomass by 94.5, 95.5 and 100%, respectively in plastic mulched rice with SMR. The reductions in weed biomass due to plastic mulching of current study were corroborated by the findings of Aimrun Wayayok *et al.* (2014) on system of rice intensification farming with mulches. Manual removal of weeds at 20 and 40 DAT resulted in zero weed counts and biomass at harvest stage. With age (maximum tillering stage), plastic holes were filled up with the rice tillers and no scope lied for further emergence of weeds. No mulch-SMR rice proved congenial for emergence of 1.8 times more number of weeds than the SWR without mulch. Accordingly,

**Table 1. Weed biomass and weeding labour requirements of rice as affected by mulching and moisture regime**

| Treatment | Weed count/m$^2$ | | | Weed biomass (g/m$^2$) | | |
|---|---|---|---|---|---|---|
| | 20 DAT | 40 DAT | At harvest | 20 DAT | 40 DAT | At harvest |
| No mulch and saturation moisture (SM) | 10.23 (103.4) | 6.40 (66.5) | 3.30 (20.4) | 10.48 (109.3) | 9.18 (83.7) | 6.37 (40.1) |
| Black polythene mulch and SM | 2.65 (6.5) | 2.00 (3.5) | 0.71 (0.0) | 2.24 (4.5) | 1.14 (1.5) | 0.71 (0.0) |
| Transparent polythene mulch and SM | 2.74 (7.0) | 2.00 (3.5) | 0.71 (0.0) | 2.35 (5.0) | 1.58 (2.0) | 0.71(0.0) |
| No mulch and 5 cm standing water (SW) | 6.31 (75.3) | 4.73 (36.9) | 2.79 (14.3) | 9.31 (86.2) | 6.29 (39.1) | 4.69 (21.5) |
| LSD (p=0.05) | 0.38 | 0.22 | 0.18 | 0.33 | 0.27 | 0.49 |

Original values in parentheses were subjected to square root $\sqrt{x+0.5}$ transformation.

no mulch-SMR rice had 37.3 (26.8), 80.2 (114.1) and 42.7% (86.5) higher weed count (weed biomass) at 20, 40 DAT and harvest stage than the SWR rice. In 5 cm standing water,water loving weeds only emerged, but SMR favoured germination of both water loving and aerobic conditions requiring weeds equally and thus higher weed count and biomass was recorded than SWR crop. A similar difference in weed flora and weed biomass of transplanted rice due to standing water depth reported by Kent and Johnson (2001), Haefele *et al.* (2004) and Duttarganvi *et al.* (2016) supports the current findings.

### Weed control efficiency

Weed biomass differences have been reflected in weed control efficiency (WCE) and labour required for weeding (**Table 2**). The increases in weed biomass in no mulch-SMR over no mulch-SWR have been translated into reduced weed control efficiencies. Thus no mulch- SMR had negative (-) WCE values as weed biomass increased over bench mark (SWR). It ranged from -26.8, -114.1 and -86.5% at 20, 40 DAT and harvest stages, respectively. The decreasing WCE values with age of rice crop in SMR-no mulch rice was ascribed to the fact that at 20 DAT weeds were small and had low biomass despite of higher weed count. At 40 DAT and harvest stage, higher weed count was reflected in higher weed biomass also. A complete weed control achieved with polythene mulching in tomato by Anzalone *et al.* (2010) corroborates the current research findings.

### Labour requirement for weeding

On account of higher weed count and weed biomass, 50% additional man days were required for two hand weedings in no mulch-SMR than no mulch-SWR rice (20 man days) (**Table 2**). Mulched treatments have little weed pressure as evident from the weed count and weed biomass (**Table 1**). On account of reduced weed count and weed biomass of mulched-SMR treatments, manual labour required for weeding was reduced by 15 times (2 labourers/ha).

### Yield and water economy

Saturation moisture regime without mulching has resulted in significant reduction in grain yield (7.1%) as compared to SWR (4.79 t/ha) that were brought to statistically at par level with plastic mulching (**Table 3**). Same was the trend for straw yield also. Saturation moisture rice without mulch has resulted into 35% water savings over no mulch-SWR culture (**Table 3**). An additional 30% savings in irrigation water (15 cm) were brought up by plastic mulching with SMR as compared to SMR alone. Thus water productivity of SWR (47.9 kg/ha-cm) was enhanced by 43% with shifting to SMR. Further, SMR water productivity (68.5 kg/ha-cm) was enhanced by 35.8% with plastic mulching (93 kg/ha-cm). Savings of water due to reduced weed count and biomass was not assessed in the study. However, the savings in water due to mulching were due to combined effect of reduced evaporation and transpiration from weeds. They need to be partitioned through separate studies.

### Economics

Economics of rice cultivation was assessed from enhanced yield, reduced water consumption, additional costs from plastic mulch and labour inputs for weeding/irrigation (**Table 4**). Cost of cultivation of transplanted rice with 5 cm SWR was ` 45000/ha. In SMR, additional costs for weeding (10 man days) and

**Table 2. Weed control efficiency and labour requirements for weeding of rice as affected by mulching and moisture regime**

| Treatment | Weed control efficiency (%) | | | Labour requirement and their cost of weeding | |
|---|---|---|---|---|---|
| | 20 DAT | 40 DAT | At harvest | Man days | Cost (`/ha) |
| No mulch and saturation moisture rice (SMR) | -26.8 | -114.1 | -86.5 | 30 | 9000 |
| Black polythene mulch and SMR | 94.8 | 96.2 | 100.0 | 2 | 600 |
| Transparent polythene mulch and SMR | 94.2 | 94.9 | 100.0 | 2 | 600 |
| No mulch and 5 cm standing water rice (SWR) | - | - | - | 20 | 6000 |

**Table 3. Water savings in rice as affected by plastic mulching and moisture regime**

| Treatment | Grain yield (t/ha) | Straw yield (t/ha) | Mean water use (cm)* | Water productivity (kg/ha-cm) |
|---|---|---|---|---|
| No mulch and saturation moisture (SM) | 4.45 | 6.52 | 65 | 68.5 |
| Black polythene mulch and SM | 4.61 | 6.70 | 50 | 92.2 |
| Transparent polythene mulch and SM | 4.69 | 6.88 | 50 | 93.8 |
| No mulch and 5 cm standing water (SW) | 4.79 | 7.08 | 100 | 47.9 |
| LSD (p=0.05) | 0.190 | 0.312 | 10.3 | 4.29 |

*From transplanting to – harvest

**Table 4. Economics of rice cultivation as affected by mulching and moisture regime**

| Treatment | Cost of cultivation (x10$^{3}$ `/ha) | Gross returns (x10$^{3}$ `/ha) | Net returns (x10$^{3}$ `/ha) | B -C ratio |
|---|---|---|---|---|
| No mulch and saturation moisture rice (SMR) | 50.10 | 80.83 | 30.73 | 1.61 |
| Black polythene mulch and SMR | 64.10 | 83.60 | 19.50 | 1.30 |
| Transparent polythene mulch and SMR | 64.10 | 85.21 | 21.11 | 1.33 |
| No mulch and 5 cm standing water rice (SWR) | 45.00 | 87.16 | 42.16 | 1.94 |
| LSD (p=0.05) | - | - | 5.02 | 0.25 |

irrigations (7 man days) were incurred which increased cost of cultivation by ` 5100/ha over SWR. In plastic mulching-SMR treatments, additional cost of plastics (` 20,000/ha) and labour for its laying/careful planting (15 man days) were incurred while labour for weeding were reduced by 18 man days as compared to SWR rice and thus had ` 19,100/ha higher cultivation cost. Net income and benefit-cost (BC) ratio were highest with 5 cm SWR rice cultivation. Plastic mulching remained least profitable as compared to no mulch SWR and SMR treatments. The low income in plastic mulching was ascribed to higher costs incurred for plastics. In the current study, life of plastics was taken as one season. If we take higher life period for plastics (2-4 seasons), then their cost would decrease and could become more profitable.

Saturation moisture regime rice without polythene mulch saved water considerably with higher water productivity compared to 5 standing water rice but it encountered more weed pressure and yield penalities making it less profitable. Plastic mulching could contribute to the success of saturation moisture rice cultivation a possibility in future but its cost, durability and safer disposal at the end of day are causes of major concern. In organic farms, plastic mulches preferably bio-degradable may be more acceptable than herbicides. There is a need to reduce cost of plastics for use in rice culture and also need to evolve biodegradable plastics that makes their use more economical and ecologically benign. Use of plastic mulches would become profitable preposition, if irrigation water is priced that is most likely in near future and plastics would become handy in reducing evaporation water losses and weed loads.

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