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Research Paper

# Influence of moisture-management practices on productivity, profitability and energy dynamics of rainfed maize (*Zea mays*) in semi-arid sub-tropical climate

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## ABSTRACT

A field experiment was conducted at the ICAR-Indian Agricultural Research Institute, New Delhi, during the rainy (*kharif*) seasons of 2014 and 2015, to study the impact of moisture-conservation techniques on growth, productivity and profitability of maize (*Zea mays* L.). The experiment was laid out in a randomized block design with 3 replications in a fixed lay-out. The treatments consisted of 4 moisture-conservation practices, viz. ridge and furrow (RF), RF + crop residue (CR) @ 4 t/ha, RF + CR @ 2 t/ha + VAM and flat sowing (FS). Among different moisture conservation techniques, RF with 4 t/ha CR recorded significant effect on growth parameters, viz. plant height, dry-matter accumulation (DMA) and leaf-area index (LAI) of maize in comparison to non-residue plots and FS. Values of canopy temperature depression (CTD) were significantly influenced by treatments 30 and 60 days after sowing (DAS), but remained unaffected at 90 DAS. SPAD values at 30, 60 and 90 DAS differed significantly at all stages and showed normal curve pattern with maximum values at 60 DAS. The treatment crop residue @ 4 t/ha in RF system produced numerically higher grain and stover yields of 3.43 and 9.51 t/ha respectively. Maize planted under RF with 4 t/ha CR exhibited significantly higher water-use efficiency (WUE) of 12.3 kg/ha-mm, followed by RF + CR 2 t/ha + VAM (10.9 kg/ha-mm) as compared to FS (8.45 kg/ha-mm) maximum net returns were obtained under RF + CR 4 t/ha ($35.8 \times 10^3$₹/ha) and the least under FS ($22.7 \times 10^3$₹/ha). Residue-based treatment, RF + CR 4 t/ha resulted in benefit: cost ratio of maximum value (1.39) maximum energy intensiveness (2.32 MJ/₹) and specific energy (17.57 MJ/kg) were also obtained for treatment RF + CR 4 t/ha.

***Key words*** **:** Flat sowing, Maize, Residue, Ridge and furrow, VAM, Water-use efficiency

India possess about 141.58 million ha net sown area, out of which, 58% (80 million ha) is rain shadow area. It contributes 40% to India's foodgrains production and supports 66% livestock population (GoI, 2016). Likewise, 40% of the population depends on rainfed agriculture and its performance is critical in enhancing production, achieving and sustaining high agricultural growth in years to come (CRIDA, 2015). Maize (*Zea mays* L.) is one of the versatile crops having wider adaptability under diverse agro-climatic condition. In addition to essential food for human being and quality feedstuff for animals, it also serves as a basic raw material to different industrial products.

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In India, rainfed maize is cultivated in southern Rajasthan, Madhya Pradesh, Himachal Pradesh, Jammu, Gujarat, Karnataka, Odisha and north-eastern region. The average productivity is as low as 0.89 t/ha to as high as 2.53 t/ha, indicating large variation and scope for productivity enhancement. There is a need for improving rainfed maize productivity as well as cropping intensity of the area through effective moisture-conservation measures. *In-situ* application of crop residues and division of field in beds and furrows could be used as low-cost input technology to conserve more rainwater in soil by minimizing runoff from the soil surface under scarcity situations (Ravisankar *et al.,* 2014).

Retention of crop residue adds organic matter which improves the quality of the seedbed, increase the water infiltration and retention capacity of the soil, reduces the evaporation of soil moisture, fixes carbon by capturing carbon dioxide from atmosphere and retains it in the soil (Bhale and Wanjari, 2009). Crop residues have competing uses like fodder in rainfed areas because of dominance of livestock, further more costs are also incurred in their application. Therefore, it is necessary that a suitable amount should be applied to enhance crop productivity in a cost-effective manner. Keeping these actualities in view, the present investigation was carried out to study the effect of moisture-conserving practices on performance of rainfed maize.

## MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) season of 2014 and 2015 at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi (28°38' 23' N, 77°09' 27' E, 228.6 m above mean-sea level) in a semi-arid subtropical climatic region. It is characterized by extreme temperatures, the annual maximum temperature goes up to as high as 45°C in summer, whereas the minimum temperature dips to as low as 0–1°C in winter. Summers are long (early April–August) with the monsoon setting in between July and September. The total rainfall received during the crop season of 2014 and 2015 was 395.4 and 710 mm respectively. Out of which, effective rainfall was 230.5 mm (58.3%) and 329 mm (46.4%) in first and second year respectively. Soil was sandy loam in texture and slightly alkaline in reaction (*p*H 7.7). Soil was low in organic carbon (4.6 g/kg) and available nitrogen (135 kg/ha) and medium in available P (13.2 kg/ha) and K (180 kg/ha).

The treatments consisted of moisture-conservation practices in the *kharif* season maize, viz. ridges and furrows (RF), RF + crop residue (CR) @ 4 t/ha, RF + CR @ 2 t/ha + vesicular arbuscular mycorhiza (VAM) and flat sowing (FS) as control. The experiment was laid-out in a randomized block design with 3 replications. In FS, field was prepared with a disc plough followed by 2 passes of a disc harrow and planking in the last to have a uniform seedbed of fine tilth. On this seed bed, the RF treatment were executed. Crop residues was applied by spreading the material uniformly on the field just after sowing. Maize variety 'Pusa composite 3' was sown on 7$^{th}$ and 2nd July 2014 and 2015 respectively with a spacing of 60 cm. Uniform doses of N, $P_2O_5$ and $K_2O$ @ 120 : 60 : 40 kg/ha were applied. Entire quantity of phosphorus and potassium was applied basal through diammonium phosphate (DAP) and muriate of potash (MoP) respectively, at the time of sowing, whereas N was applied in 2 equal split through urea.

Canopy temperature depression (CTD) was measured with the help of infrared thermometer inside the plant canopy and compared with prevailing ambient temperature. Leaf chlorophyll concentration of the upper most fully-expanded leaves was assessed with a portable chlorophyll meter (SPAD-502, Tokyo, Japan) and expressed in arbitrary absorbance (or SPAD) values. In addition, leaf area was measured with a leaf area meter (LICOR-3000). Water-use efficiency (WUE) was calculated by dividing grain yield with consumptive use (~ET) of water. The economics was computed using prevailing prices of inputs and outputs. Mean data of 2 years (2014 and 2015) obtained from various studies was statistically analyzed in randomized block design (RBD) using the technique of analysis of variance (ANOVA). The differences between the treatment means were tested as to their statistical significance with critical difference (CD) value at 5%(Gomez and Gomez, 2010).

## RESULTS AND DISCUSSION

### *Growth parameters*

Among the moisture-conservation treatments, RF + CR 4 t/ha gave tallest plants, maximum dry-matter and LAI of maize in comparison to non-residue plots and FS (Table 1). At harvest, significantly taller plants were observed under RF + 4 t/ha CR treatment with the increase of 20.7% over FS. Further more RF + 4 t/ha CR and RF + 2 t/ha + VAM treatments were statistically at par. Dry-matter accumulation at harvesting showed statistically superior value of 160 g/plant in treatment RF + 4 t/ha CR of other treatments. Simmilar LAI at 90 DAS was the maximum under treatment RF + 4 t/ha CR of over rest of the

**Table 1.** Effect of moisture-conservation techniques on growth and yield attributes of maize (mean data of 2014 and 2015)

| Treatment | Plant height at harvest (cm) | DMA at harvesting (g/plant) | LAI at 90 DAS | Cob length (cm) | Cob girth (cm) | Grains/ cob | Grain weight/ cob (g) | 1,000-grain weight (g) | Shelling (%) |
|---|---|---|---|---|---|---|---|---|---|
| Ridge and furrows (RF) | 198 | 140 | 3.67 | 17.03 | 12.93 | 383 | 78.0 | 235 | 66.67 |
| RF + 4 t/ha crop residue (CR) | 216 | 160 | 4.35 | 18.57 | 14.18 | 418 | 85.2 | 244 | 70.99 |
| RF + 2 t/ha CR + VAM | 208 | 150 | 4.00 | 18.34 | 13.20 | 402 | 81.7 | 237 | 69.44 |
| Flat sowing | 179 | 126 | 3.35 | 15.31 | 12.36 | 354 | 74.8 | 230 | 65.45 |
| SEm± | 5 | 2 | 0.06 | 0.35 | 0.33 | 8.7 | 1.6 | 5.2 | 0.52 |
| CD (P=0.05) | 17 | 7 | 0.21 | 1.21 | 1.14 | 30.2 | NS | NS | NS |

DMA, Dry matter accumulation; DAS, days after sowing; LAI, Leaf-area index; VAM, vascular arbuscular mycohriza treatments. The lowest values of DMA and LAI were obtained in FS. Better performance of maize under RF+CR can be attributed to infiltration of excess rainwater impounded in furrows and less evaporation. The increase in soil-moisture content may be owing to better tillage practices and sowing of maize on ridges (Amin *et al.,* 2006).

### *Physiological indices*

Different moisture-conservation treatments significantly influenced physiological parameters, viz. canopy temperature depression (CTD), SPAD value and normalized difference vegetation index (NDVI) measured at 30 days interval during the crop growth period (Fig. 1). The CTD values were significantly influenced by treatments at 30 and 60 DAS, but remained unaffected at 90 DAS. At initial stage (30 DAS), RF + 4 t/ha CR recorded the maximum value (1.40°C) for CTD, which was significantly higher over all other measures, while the lowest value (0.72) recorded in FS. The values peaked at 30 DAS and thereafter showed steady drop with lowest value at 90 DAS.

The SPAD values at 30, 60 and 90 DAS differed significantly and showed normal curve pattern. Among different treatments, RF + 4 t/ha CR steadily registered significantly higher values of 37.6, 39.1 and 33.7 at 30, 60 and 90 DAS respectively. Residue application with RF planting of maize ensured higher moisture availability. This gave higher canopy coolness in treatment plots as of other treatments and registered higher CTD values.

Green seeker measures the leaf reflectance *vis-à-vis* NDVI which is directly proportional to leaf area. The NDVI values over the crop stages indicates peak values at 60 DAS and thereafter a dip was seen. The treatments were significantly influenced at 60 DAS only. At 60 DAS, RF + 4 t/ha CR revealed the maximum value (0.69) which was 30% higher over FS (0.53). The NDVI gave statistically at par values at initial growth stage, indicating uniformity in leaf-area expansion in different treatments.

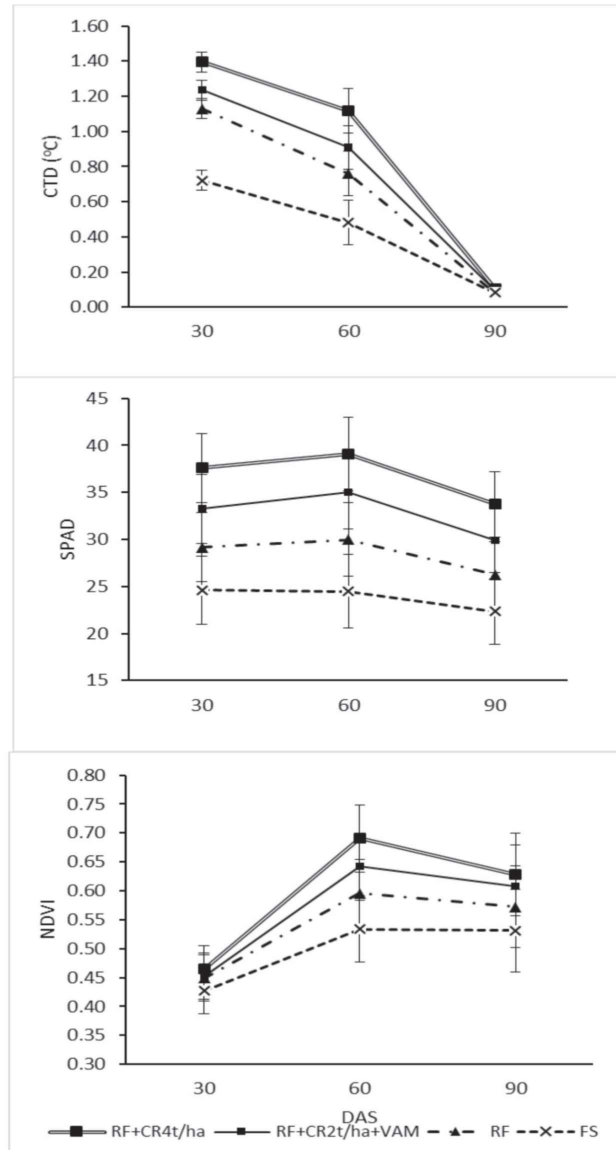


**Fig. 1.** Physiological parameters under of different moisture conservation practices (CTD, Canapy temperature difference; SPAD; NDVI, normal difference vegetation index) in maize

**Table 2.** Effect of moisture conservation techniques on economics and energy parameters of maize (mean data of 2014 and 2015)

| Treatment | Cob yield (t/ha) | Grain yield (t/ha) | Stover yield (t/ha) | Harvest index (%) | CoC (× $10^3$ ₹ /ha) | Net returns (× $10^3$ ₹/ha) | Benefit: cost ratio | Energy output– input ratio | Energy productivity (kg/GJ) | Energy intensiveness (MJ/₹) | Specific energy (GJ/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ridge and furrows (RF) | 3.97 | 2.65 | 8.16 | 32.58 | 21.1 | 27.7 | 1.31 | 11.61 | 287 | 0.44 | 3.55 |
| RF + 4 t/ha crop residue (CR) | 4.83 | 3.43 | 9.51 | 34.93 | 25.7 | 35.8 | 1.39 | 2.18 | 57 | 2.32 | 17.57 |
| RF + 2 t/ha CR + VAM | 4.46 | 3.10 | 8.59 | 34.98 | 24.6 | 31.0 | 1.26 | 3.35 | 88 | 1.43 | 11.41 |
| Flat sowing | 3.56 | 2.34 | 7.25 | 32.35 | 20.4 | 22.8 | 1.12 | 9.65 | 237 | 0.48 | 4.29 |
| SEm± | 0.13 | 0.10 | 0.24 | 0.67 | - | 1.5 | 0.07 | 0.17 | 8 | - | 0.26 |
| CD (P=0.05) | 0.47 | 0.33 | 0.84 | NS | - | 5.0 | 0.23 | 0.58 | 29 | - | 0.91 |

CoC, Cost of cultivation

Govaerts and Verhulst (2010) reported similar findings for NDVI on maize under different treatments.

### *Yield attributes*

Moisture-conservation techniques had significant effect on cob length, cob girth, grains/cob but not on grain weight/cob, shelling per cent and 1,000-grain weight (Table 1). The RF-based treatments were significantly better than FS (control), maximum cob length and cob girth were observed in RF + CR 4 t/ha which was at par to RF + CR 2 t/ha + VAM. Significantly higher number of grains/cob were observed in treatment RF + CR 4 t/ha which was 18% higher over FS. The significant changes in yield attributes is attributed to moisture conservation and residue application leading to better growth, more photosynthates accumulation and nutrients availability to plants (Ghosh *et al.,* 2016).

### *Yield*

Moisture-conservation treatment, RF + CR 4 t/ha recorded significantly higher cob yield, which was 21 and 35% greater than sole RF and FS treatments respectively (Table 2). The treatment also resulted in significantly higher grain yield (3.43 t/ha) and stover yield (9.51 t/ha) than RF and FS. The increase in stover yield was11, 17 and 31% higher over RF + CR 2 t/ha + VAM, RF and FS treatments, respectively. However, none of the treatment brought any significant improvement in harvest index of maize.

Significantly higher grain and stover yields though moisture conservation and residue application can be attributed to better plant establishment during initial phase and onward robust growth. Arora and Bhatt (2008) have also reported 10.6% increase in maize grain yield with RF sowing in comparison to farmers' practice. Similar increase in maize fodder yields with mulch application in rainfed area of Punjab was reported by Khera and Singh (1998).

### *Water-use efficiency*

The term efficiency or productivity refers to output: input ratio. If the ratio is more, the system is said to be more efficient or productive. Enhancing water-use efficiency (WUE) of rainfed maize is important requisite for sustainable maize production, particularly in areas having low and erratic rainfall pattern. Ridges and furrows + 4 t/ha CR resulted in significantly higher WUE than FS. The Fig. 2 showed that application of CR substantially reduced the consumptive use of water with moisture conservation. Maize planted under RF + 4 t/ha CR recorded the maximum WUE (12.4 kg/ha-mm) followed by RF + CR 2 t/ha + VAM (11.2 kg/ha-mm). While the minimum WUE was recorded in FS (8.45 kg/ha-mm) which was at par to RF treatment (9.65 kg/ha-mm). The significant improvement in WUE is a reflection of reduction in consumptive use of water due to crop residue. Application moisture-conserving treatments led to decrease in evapotranspiration and increase in long-term soil moisture storage as well as availability leading to improved WUE (Singh *et al.,* 2014).

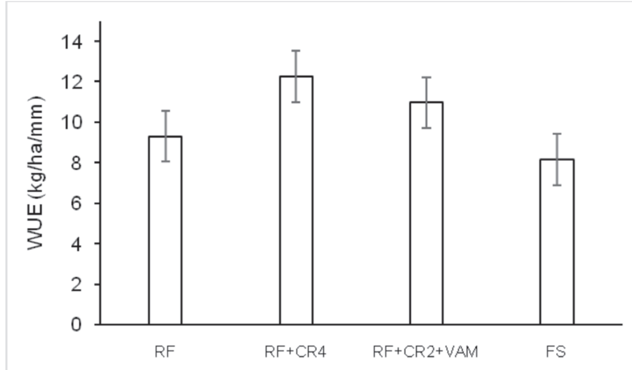


**Fig. 2.** Water use efficiency of maize as influenced by different moisture-conservation practices (WUE, Water use efficiency; RF, ridge and furrow; CR 4, crop residue @ 4 tonnes/ha; RF + CR 2 + VAM), crop residue @ 2 t/ha + vesicular arbuscular mycorhyza; FS, flat sowing)

### *Economics*

The cost of cultivation of maize under different moisture-conservation treatments varied from lower most in FS to maximum under RF + CR 4 t/ha. This variation is attributed to modifications in land-preparation techniques and quantity of residue applied. The maximum net returns were received under RF + CR 4 t/ha (35.8 × $10^3$₹/ha) which was at par with RF + 2 t/ha + VAM and least under FS (22.8 × $10^3$₹/ha). The RF + CR 4 t/ha showed significantly higher benefit: cost ratio (1.39) over FS which was followed by RF treatment (1.31). Similar higher gross and net returns with residue application in maize reported by Kumar *et al.* (2015).

### *Energy indices*

Different energy indices concerning to rainfed maize production were significantly influenced by treatments (Table 2). Energy output: input ratio was recorded highest in sole RF, while minimum value was residue-based treatment RF + 4 t/ha CR. A similar trend was observed for energy productivity too with maximum and minimum values in RF and RF + 4 t/ha CR, respectively. Application of high quantity of residue greatly reduced energy output/input ratio and energy productivity. Lower energy output: input ratio in maize production systems is due to higher energy inputs in these systems (Lorzadeh *et al.,* 2012). Energy intensiveness and specific energy for different

**Table 3.** Correlation among different parameters of maize (mean of 2014 and 2015)

| Characters | CY (t/ha) | GY (t/ha) | SY (t/ha) | HI (%) | TW (g) | CL (cm) | CG (cm) | Grains/ cob | GW/ cob (g) | Shelling (%) | PH# (cm) | DMA# (g/plant) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CY(t/ha) | | | | | | | | | | | | |
| GY(t/ha) | 0.995** | | | | | | | | | | | |
| SY(t/ha) | 0.916** | 0.930** | | | | | | | | | | |
| HI (%) | 0.866** | 0.853** | 0.616* | | | | | | | | | |
| TW(g) | 0.686* | 0.658* | 0.544NS | 0.669* | | | | | | | | |
| CL (cm) | 0.827** | 0.822** | 0.749** | 0.683* | 0.551NS | | | | | | | |
| CG (cm) | 0.796** | 0.810** | 0.778** | 0.637* | 0.743** | 0.690* | | | | | | |
| Grains/cob | 0.839** | 0.853** | 0.807** | 0.659* | 0.468 NS | 0.725** | 0.611* | | | | | |
| GW/cob (g) | 0.901** | 0.915** | 0.946** | 0.654* | 0.465 NS | 0.691* | 0.622* | 0.892** | | | | |
| Shelling (%) | 0.888** | 0.929** | 0.886** | 0.755** | 0.515 NS | 0.743** | 0.799** | 0.830** | 0.863** | | | |
| PH (cm) | 0.825** | 0.824** | 0.721** | 0.728** | 0.465 NS | 0.841** | 0.788** | 0.755** | 0.660* | 0.773** | | |
| DMA (g/plant) | 0.899** | 0.920** | 0.913** | 0.649* | 0.478 NS | 0.840** | 0.734** | 0.907** | 0.915** | 0.894** | 0.825** | |
| LAI## | 0.885** | 0.893** | 0.845** | 0.678* | 0.500 NS | 0.858** | 0.772** | 0.910** | 0.833** | 0.842** | 0.921** | 0.963** |

# at harvest, ## at 90 DASCY, Cob yield; GY, grain yield; SY, stover yield, HI, harvest index; TW, test (1,000-grain) weight; CL, cob length; CG, cob girth; PH, plant height, DMA, dry matter accumulation; LAI-leaf area index

treatments were calculated on the basis of cost of cultivation and grain yield of maize which indicate energy produced in each treatment/unit investment and per unit of yield, respectively. Maximum value of energy intensiveness (2.32 MJ/₹) and specific energy (17.37 GJ/kg) were obtained for treatment RF + CR 4 t/ha.

### *Correlation studies*

The correlation analysis was done to obtain details on the association and relationship among different quantitative traits of maize (Table 3). Most of the parameters exhibited significant correlation barring 1,000-weight, which showed non-significant relationship with other yield attributes. All the yield parameters, cob yield, grain yield and stover yield had highly significant correlation with growth parameters as well as yield attributes. Harvest index showed significance only at 5% for most of the parameters. Correlation among yield attributes and plant growth parameters showed lower degree of relationship in comparison to yield parameters. Dry matter accumulation and LAI showed highly significant values (0.96) indicating that importance of leaf-area expansion and photosynthesis in maize. However, cob length and cob girth showed lower degree of correlation across different parameters. Similar findings are also reported byAbadassi (2015).

From the findings – It can be concluded that in rainfed conditions, planting of maize can be done on ridges along with application of crop residue @ 4 t/ha or with 2 t/ha CR + VAM for achieving higher productivity and profitability. The treatment yielded good results in terms of physiological parameters and improved WUE. The increase in grain yield ranged 15–25% and performed efficiently on the basis of different energy indices. The findings have implications for rainfed areas with good economic returns.

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