Forage Res., **47** (1) : pp. 125-129 (2021) **http://forageresearch.in**

RESPONSE OF ZERO-TILL RAINFED MAIZE TO SUPER ABSORBENT POLYMER AND MULCHING IN MAIZE-WHEAT CROPPING SYSTEM UNDER SEMI-ARID CONDITIONS OF HARYANA

SURESH KUMAR[1]*, R. K. ARYA[2], NARENDER SINGH[3] AND SATPAL[2]

[1]Directorate of Research, CCS Haryana Agricultural University, Hisar, 125004 (Haryana), India
[2]Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar (Haryana), 125004, India
[3]CCSHAU, Regional Research Station, Karnal, 132001 (Haryana), India
**(e-mail : sureshsilla@hau.ac.in)*

(Received : 2 June 2021; Accepted : 28 June 2021)

SUMMARY

A field experiment was conducted at Ram Dhan Singh Seed Farm, CCS Haryana Agricultural University, Hisar (Haryana) to evaluate the response of zero-till rainfed maize to super absorbent polymer and mulching in maize-wheat cropping system under semi-arid conditions. The experiment was laid out in a split-plot design with combination of two levels of tillage practice (conventional and zero tillage) and two levels of mulch application (without mulching and mulching @ 4 tonnes/ha) in main plots and 3 levels of hydrogel (No hydrogel, hydrogel @ 2.5 kg/ha, hydrogel @ 5.0 kg/ha) in sub-plots with three replications. The soil of the experimental field low in available nitrogen, medium available P and high in available K. Among the tillage practices, zero till sown maize crop recorded higher grain yield (5466 kg/ha), water use efficiency (23.5 kg/ha-mm) and benefit cost ratio (3.98) as compared to the maize crop sown after conventional tillage. Among the mulching levels, mulching @ 4 t/ha in maize crop recorded higher grain yield (5058 kg/ha), water use efficiency (21.7 kg/ha-mm) and benefit cost ratio (3.02) as compared to the maize crop without mulching. Among the hydrogel levels, the maximum grain yield (4921 kg/ha), was produced by application of hydrogel @ 5.0 kg/ha, which was significantly superior to no hydrogel, but statistically at par to hydrogel @ 2.5 kg/ha. Net returns was achieved maximum with application hydrogel @ 2.5 kg/ha, but the benefit cost ratio decreased with hydrogel application. Maximum grain yield (5546 kg/ha) was obtained in zero tillage with mulch/residue retention @ 4 t/ha.The grain yield of succeeding wheat was not influenced markedly by the tillage practices, mulching and hydrogel application in maize. System maize equivalent followed the trend as per grain yield of maize.

Key words : Rainfed, maize, zero tillage, hydrogel, mulch, residue, water-use efficiency

Maize (*Zea mays* L.) is one of the most significant cereal crops grown over different environment and geographical conditions for the purpose of food for man, feed for livestock and raw material for industrial products. It is grown on 193.7 million hectare area in more than 170 countries across the globe with 1147.7 million MT of production and productivity of 5.75 t/ha (FAOSTAT, 2020). It ranks 3rd in the world in production after wheat and rice, but in productivity it transcends all cereals, that is why, it is known as 'queen of cereals' or 'miracle crop'. In India, the area, production and productivity of maize was 9.2 million hectare, 27.8 million tonnes and 2965 kg/ha, respectively, during 2018-19 (ICAR-IIMR, 2021). The production areas of maize are ever-increasing due to its increasing use in poultry and dairy farms and the farmers are also attracted to include it in their crop diversification system in India. Being a C_4 plant, maize is fast growing, sweet and high yielding and a good source of nutrients for human beings as a cereal crop and animals as feed and fodder (Arya *et al.*, 2020). In India, maize is mainly grown as rainfed crop with 80 percent of its area under rainfed conditions and maize-wheat cropping system is followed in upland irrigated (normally wheat is irrigated) ecologies of the Indo-Gangetic Plains (IGP) of India. In arid and semi-arid regions water stress is a major limiting factor of crop productivity. In most cases, continuous moisture stress during critical growth stages of maize along with reduced nutrient input leads to reduction in maize yield (Shivakumar *et al.*, 2019). Maize is planted with the conventional tillage followed by flat planting mechanically or manually since long. Recently, zero tillage been advocated in various maize based cropping systems and found cost effective and environment friendly with benefits like reduced soil evaporation rate, Modified water infiltration and soil aeration, increase total nitrogen and microbial biomass, reduction in input costs for labour, fuel, tractors, and other equipments, greater economic returns (Monneveux *et al*., 2006).

Under various environmental conditions, organic mulch had positive effects on soil and water conservation. Mulch application rate greatly impact soil and water loss; leading to reduction in the rates of soil loss and runoff (Li *et al*., 2021). With the increasing use of combine harvester, a large amount of winter wheat straw is retained in the field after harvest, which can be effectively utilized for mulching in the coming maize crop (Shen *et al*., 2012). Recently, hydrogel, a super absorbent polymer has been identified for use in seed germination, seedling emergence, seedling establishment, and seedlings survival of maize. Moreover, studies on the effects of hydrogel on the growth and productivity of maize in specific soil texture, soil moisture and pH, and the hydrogel levels are also very important. Keeping this view, the present study was carried out to evaluate the response of zero-till rainfed maize to super absorbent polymer and mulching in maize-wheat cropping system under semi-arid conditions of Haryana.

MATERIALS AND METHODS

The experiment was conducted during *kharif* season of 2015 at Rao Bahadur Ram Dhan Singh Seed Farm, CCS Haryana Agricultural University, Hisar, India at 29º47′ N latitude and 75°47′ E longitude in a semi-arid climate having loamy sand soil. The site experiences semi-arid and sub-tropical climate with hot dry summer and severe cold winter, with maximum temperature above 45°C during hot summer months and minimum temperature of sub zero during winter months of December and January. The average annual rainfall of the area is around 450 mm of which, 70-80 per cent is received during monsoon period i.e., July to September and the rest is received in showers of cyclic rains during the winter and spring seasons. The weekly weather parameters pertaining to standard meteorological weeks during the present study have been depicted in Fig. 1. The experiment was laid out in a split-plot design with combination of two levels of tillage practice (conventional and zero tillage) and two levels of mulch application (without mulching and mulching @ 4 tonnes/ha) in main plots and 3 levels of hydrogel doses (No hydrogel, hydrogel @ 2.5 kg/ha, hydrogel @ 5.0 kg/ha) in sub-plots with three

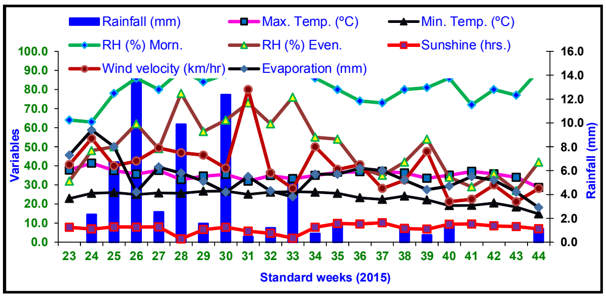

Fig. 1. Mean weekly weather data for crop season (2015).

replications. The soil of the experimental field was low in available nitrogen, medium in available P and high in available K. The zero-till drill was run once before actual sowing for making rows for placement of hydrogel, which was applied in rows by placing it below the seed. Wheat straw was used as mulching material in conventional till plots and wheat residues were left in zero till plots as per the treatments. The maize hybrid 'HQPM 10' was sown on flat beds with a spacing of 40 x 25 cm in conserved soil moisture and raised as per the standard agronomic practices except the irrigation. Total post-sown rainfall received was 163.1 mm during the maize season. After the harvest of the maize crop, wheat variety WH 1105 was sown in with conventional tillage and raised under irrigated conditions with recommended agronomic practices. The data recorded were subjected to statistical analysis as per the standard procedure using the software OPSTAT (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

Biological, grain and stover yield of Maize

Yield of the any crop is resultant of several factors such as environmental conditions above and below the soil as well as physical and biological reactions taking place within the plant system. Several processes and reactions taking place in the plant system are very complex and hard to draw the cause and effect relationships, which lead finally to yield of the crop. The biological, grain and stover yield of rainfed maize were significantly affected by tillage practices, mulching and hydrogel application. Among the tillage practices, zero till sown maize crop yielded higher biological (11355 kg/ha), grain (5466 kg/ha) and stover yield (5889 kg/ha) as compared to the maize crop sown after conventional tillage (8668, 4041 and 4627 kg/ha, respectively) (Table 1). The higher biological, grain and stover yield under zero tillage in rainfed maize was due to more number of plants at harvest and

TABLE 1
Yield of rainfed maize and system yield as influenced by tillage, mulching and hydrogel application in maize

Treatments	Biological yield of maize (kg/ha)	Grain yield of maize (kg/ha)	Stover yield of maize (kg/ha)	Grain yield of succeeding wheat (kg/ha)	Maize equivalent yield in rabi season (kg/ha)	System maize equivalent yield (kg/ha)
Tillage practices						
Conventional tillage	8668	4041	4627	4018	3584	7625
Zero tillage	11355	5466	5889	3909	3486	8952
SE (m) ±	98	61	46	48	43	72
C. D. (P= 0.05)	339	210	158	NS	NS	248
Mulching						
No mulching	9450	4449	5002	3922	3498	7946
Mulching @ 4 t/ha	10573	5058	5515	4005	3572	8631
SE (m) ±	98	61	46	48	43	72
C. D. (P= 0.05)	339	210	158	NS	NS	248
Hydrogel application						
Control (No hydrogel)	9644	4544	5100	3934	3509	8052
Hydrogel 2.5 (kg/ha)	10068	4795	5273	3968	3539	8334
Hydrogel 5.0 (kg/ha)	10323	4921	5402	3989	3558	8479
SE (m) ±	100	45	73	80	71	62
C. D. (P= 0.05)	299	134	219	NS	NS	185

higher values of yield attributes (data not given), which could be ascribed to higher water availability to crop plants in zero tilage, essentially through soil water capture and root uptake capacity and increase total nitrogen and microbial biomass (Monneveux *et al*., 2006). Similar increase in maize yield in zero tillage has also been reported by Karki *et al*. (2014).

Among the mulching levels, mulching/residue retention @ 4 t/ha in maize crop produced higher biological (10573 kg/ha), grain (5058 kg/ha) and stover yield (5515 kg/ha) as compared to the maize crop without mulching/residue retention (9459, 4449 and 5002 kg/ha, respectively) (Table 1). The mulch/residue cover resulted in adequate moisture availability at different growth stages of the crop leading to the better crop growth and yield. Shivakumar *et al.* (2019) have also reported increase in maize yield with mulching.

The hydrgel application in rainfed maize had a significant effect on its yield. The maximum biological (10323 kg/ha), grain (4921 kg/ha) and stover yield (5402 kg/ha) were produced by application of hydrogel @ 5.0 kg/ha, which was significantly superior to control (no hydrogel) but statistically at par to hydrogel @ 2.5 kg/ha (Table 1). In dry spell, hydrogel may have improved the availability of water to the crop, which indirectly improved the translocation of water, nutrients and photo assimilates leading to the higher plant growth and yield. Corroborative findings have also been reported by Shivakumar *et al.* (2019). Interaction effect of tillage and mulching was found significant and maximum grain yield (5546 kg/ha) was obtained in zero tillage with mulch/residue retention @ 4 t/ha (Table 2). Zero tillage and mulch/residue provided additive effect for better soil moisture conditions to the crop for better growth resulting into yield.

Grain yield of succeeding wheat and system yield

The grain yield of succeeding wheat as well as maize equivalent yield in *rabi* season was not influenced markedly by the tillage practices, mulching and hydrogel application in maize (Table 1). However, the system maize equivalent yield was higher (8952 kg/ha) under zero tillage sowing of maize as compared to its conventional sowing (7625 kg/ha). Likewise, mulching/residue retention @ 4 t/ha in maize crop produced higher system maize equivalent yield (8631 kg/ha), in compared to the maize crop without mulching/residue retention (7946 kg/ha) and application of hydrogel @ 5.0 kg/ha in maize produced maximum system maize equivalent yield (8479 kg/ ha), which was significantly superior to control (no hydrogel) but statistically at par to hydrogel @ 2.5 kg/ha. The variation in system maize equivalent yield was found mainly due to change in grain yield of maize.

TABLE 2
Grain yield (kg/ha) of rainfed maize as influenced by tillage practices and mulching

Treatments	No mulching	Mulching @ 4 t/ha	Mean (Tillage)
Conventional tillage	3511	4570	4041
Zero tillage	5386	5546	5466
Mean (Mulching)	4449	5058	
C. D. (P=0.05)	Tillage: 210; Mulching; 210; Tillage x mulching : 296		

Soil moisture depletion and water use efficiency

Zero till sown rainfed maize depleted lesser soil moisture (69.1 mm) as compared to conventional tillage (73.7 mm) during the crop season (Table 3). As a result, the total water use by rainfed maize from sowing to harvesting was lower under zero tillage (232.2 mm) as compared to that under conventional tillage (236.8 mm). Zero tillage affects water availability to plants, essentially through soil water capture and root uptake capacity (Monneveux *et al*., 2006). The zero till sown rainfed maize resulted in higher water use efficiency (23.5 kg/ha-mm) as compared to that sown after conventional tillage (17.1 kg/ha-mm). This increase was because of increase in grain yield of maize with lower amount of water use under zero tillage than conventional tillage system. Zero tillage enhances soil total porosity and saturated water conductivity, thereby increasing rainfall infiltration and soil water holding capacity, reducing soil evaporation, and enhancing crop growth, yield, and water use efficiency (Peng *et al*., 2019). The mulching/residue retention @ 4 t/ha resulted in higher water use efficiency (21.7 kg/ha-mm) as compared to no mulching (18.9 kg/ha-mm). Soil moisture depletion was lower (70.3 mm) by the rainfed maize crop in mulching/residue retention @ 4t/ha as compared to without mulching (72.5 mm). Hence, the total water use by rainfed maize was lower under mulching (233.4 mm) as compared to that under conventional tillage (235.6 mm). This decrease in soil moisture depletion and increase in water use efficiency in zero tillage and mulching can be ascribed to fact that the residues on the surface of no-till soils and mulching may act as an insulator, further decreasing soil temperature and reducing evaporation from the soil surface and leading to higher detention of water in soil (Karki and Shrestha, 2014).

The variation in soil moisture depletion and water use by maize due to hydrogel application was not marked. However, application of hydrogel @5.0 kg/ha least amount of soil moisture depletion (70.8 mm) and total water use (233.9 mm) and no hydrogel application recorded maximum soil moisture depletion (72.0 mm) and total water use (235.1 mm). Maximum water use efficiency (21.1 kg/ha-mm) was recorded with application of hydrogel @5.0 kg/ha. This may be because of easy accessibility of moisture and nutrients to plants in hydrogel and mulch applied treatments resulted in better root and shoot growth (Shivakumar *et al.* 2019).

Economics of maize cultivation

In the present study zero tillage fetched the higher gross returns (Rs.106126/ha) and net returns (Rs.79348/ha) and as a result higher benefit cost ratio

TABLE 3
Water use efficiency and economics of rainfed maize as influenced by tillage, mulching and hydrogel application

Treatments	Soil moisture depletion by maize (mm)	Total water use (mm)	Water use effeciency (kg/ha-mm)	Gross returns (Rs./ha)	Returns over variable cost (Rs./ha)	B : C
Tillage practices						
Conventional till	73.7	236.8	17.1	79749	35146	1.79
Zero tillage	69.1	232.2	23.5	106126	79348	3.98
Mulching						
No mulching	72.5	235.6	18.9	87298	51653	2.75
Mulching @ 4 t/ha	70.3	233.4	21.7	98577	62841	3.02
Hydrogel application						
Control (No hydrogel)	72.0	235.1	19.4	89062	56222	3.04
Hydrogel 2.5 (kg/ha)	71.4	234.5	20.5	93710	58014	2.90
Hydrogel 5.0 (kg/ha)	70.8	233.9	21.1	96040	57506	2.72

(3.98) as compared to conventional till sown maize (Rs.79749/ha, Rs.35146/ha and 1.79, respectively) (Table 3). Better returns under zero tillage was due to higher yields and lower input cost as compared to conventional tillage. Govardhanrao and Ramana (2017) also reported that zero tillage in maize fetched higher net returns as compared to conventional tillage grown maize.

The mulching/residue retention @ 4 t/ha fetched higher gross returns (Rs.98577/ha) and returns on variable cost (Rs.62841/ha) and benefit cost ratio decreased (3.02) compared to no mulching (Rs.87298/ha, Rs.51653/ha and 2.75, respectively) (Table 3). Among the hydrogel levels, maximum gross returns (Rs.96040/ha) was fetched with application of hydrogel @ 5.0 kg/ha, but returns on variable cost was maximum (Rs.58014/ha) with application of hydrogel @ 2.5 kg/ha. However, the benefit cost ratio decreased with application of hydrogel.

CONCLUSIONS

The grain yield of rainfed maize increased under zero tillage as compared to conventional and mulching/residue retention @ 4 t/ha increase yield of rainfed maize as compared to no mulching. Further, the grain yield of rainfed maize was maximum (5466 kg/ha) in zero tillage with application of mulch /residue retention @ 4 t/ha. Both zero tillage and mulching enhanced the returns over variable cost. Hydrogel @ 2.5 kg/ha increased yield of rainfed maize and returns over variable cost, but the benefit cost ratio decreased as compared to no hydrogel application.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, ICAR-Indian Institute of Maize Research for providing opportunity to conduct maize trial and financial assistance and also thankful to Regional Director, RRS, Karnal and Director, RDS Seed Farm, CCS HAU, Hisar for providing field trial facilities for the investigation.

REFERENCES

Arya, R.K., M.C. Kamboj and S. Kumar, 2020 : Evaluation of new extra-early maturing hybrids of maize (Zea mays L.) for grain yield and contributing traits under humid and semi-arid conditions of Haryana. *Ekin Journal of Crop Breeding and Genetics*, **6** : 91-95.

FAOSTAT 2020: Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data/QC.

Govardhanrao, V. and P. V. Ramana, 2017 : Economic performance of zero tillage technology in maize under agency tracts of Andhra Pradesh. *Asian Journal of Agricultural Extension, Economics & Sociology*, **16** : 1-4, Article no.AJAEES.32455

ICAR-IIMR 2021: ICAR-Indian Institute of Maize Research, Ludhiana, Punjab, India. https://iimr.icar.gov.in/

Karki, T. B. and J. Shrestha, 2014 : Maize production under no-tillage system in Nepal. *World Journal of Agricultural Research*, 2, (6A): 13-17.

Karki, TB., N. Gadal and J. Shrestha, 2014 : Studies on the conservation agriculture based practices under maize (*Zea mays* L.) based system in the hills of Nepal. International Journal of Applied Science and Biotechnology, **2**(2) : 185-192.

Li, R., Q. Li and L. Pan, 2021: Review of organic mulching effects on soil and water loss. *Archives of Agronomy and Soil Science,* **67** : 136-151.

Monneveux, P., E. Quille´ rou, C. Sanchez and J. Lopez-Cesati, 2006 : Effect of zero tillage and residues conservation on continuous maize cropping in a subtropical environment (Mexico). *Plant and Soil,* 279, 95–105 DOI 10.1007/s11104-005-0436-3.

Peng, Z., L. Wang, J. Xie, L. Li, J.A. Coulter, R. Zhang, , Z. Luo, J. Kholova, and S. Choudhary, 2019. *Agronomy*, **9** : 583. doi:10.3390/agronomy 9100583.

Shen, J. Y., D. D. Zhao, H. F. Han, X. B. Zhou, Q. Q. Li. 2012 : Effects of straw mulching on water consumption characteristics and yield of different types of summer maize plants. *Plant Soil Environ.* **58** : 161-166.

Sheoran, O. P., D. S. Tonk, L. S. Kaushik, R. C. Hasija, and R. S. Pannu, 1998 : Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda and R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar. pp. 139-143.

Shivakumar, R., T. K. Bridgit and P. K. Retheesh, 2019 : Effect of hydrogel and mulching on yield, yield attributes and economics of maize (*Zea mays* L.) in sandy soil. Internal Journal of Chemical Studies. https://www.researchgate.net/publication/344135086.