International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM April 2022, 13(4):332-338 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR2362a

Research article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.2362a

Effect of Tillage and Mulching on Growth, Yield and Economics of Maize Crops

Pramod Kumar[1], Suman Lata[2], Swapnil[3], Anuradha Sinha[4] and Digvijay Singh[3]

[1]Zonal Research Station (Birsa Agricultural University), Chianki, Palamau, Jharkhand (822 102), India
[2]Dept. of Soil Science and Agricultural Chemistry, [3]Dept. of Plant Breeding and Genetics, [4]Dept. of Horticulture (Vegetable & Floriculture), Bihar Agricultural University, Sabour, Bhagalpur, Bihar (813 210), India

Open Access

Corresponding suman.lata272@gmail.com

0000-0003-2609-9232

ABSTRACT

The field experiments were conducted during July to October, 2017, 2018 and 2019 in split plot design was laid out at Zonal Research Station farm, Chianki, Palamu, Jharkhand, India. The cultural practices included two factors i.e. the first factor included conventional tillage (CT), minimum tillage (MT), raised bed sowing (RBS), the second factor included without mulch (WM), farm waste mulch (FWM), polythene mulch (PM), soil mulch (SM). The rain water use efficiency was higher in raised bed sowing+polythene mulch (5.71 kg ha^{-1} mm^{-1}) than the other treatments but it was lowest in MT+WM (2.96 kg ha^{-1} mm^{-1}) over the three years. The high water use efficiency in the year 2019 (5.71 kg ha^{-1} mm^{-1}) influences the maximum growth and yield (5,169 kg ha^{-1})of the crop followed by 2018 (4.74 kg ha^{-1} mm^{-1}) but the minimum yield was found under minimum tillage without mulch in every year. This higher growth leads to higher stover yield and plastic mulch prevents the weeding cost which finally improved the B:C ratio (1.97) by reducing cost of cultivation and improving net return. In conclusion, minimum tillage without mulch is not recommended under dryland condition but raise bed sowing with plastic mulch is a suitable practice among all practices. This shows that raised bed practice prevent the maize crop from excess water condition and plastic mulching is helpful in increasing water use efficiency, controlling weed and maintaining temperature near root zone but no mulch condition degrade the fertile layer of soil by erosion.

KEYWORDS: Dryland, maize, mulch, rain water use efficiency, tillage

***Citation* (VANCOUVER):** Kumar et al., Effect of Tillage and Mulching on Growth, Yield and Economics of Maize Crops. *International Journal of Bio-resource and Stress Management,* 2022; 13(4), 332-338. HTTPS://DOI.ORG/10.23910/1.2022.2362a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 16th May 2021 RECEIVED in revised form on 18th February 2022 ACCEPTED in final form on 10th April 2022 PUBLISHED on 30th April 2022

1. INTRODUCTION

In recent years, scarcity of water, energy and labour, increasing production cost, decreasing farm profitability and climate-change-induced variability are major challenges faced by the farmers of South Asia. Conservation agriculture (CA) based crop management practices may increase crop productivity and profitability (Jat et al., 2019). CA-based soil and residue management coupled with crop diversification creates favourable soil environment for crop establishment. Maize is one of the most versatile crop, has the highest genetic yield potential and known as queen of cereals in the World. It is considered as the third most important food crop among the cereals in India (Verma et al., 2020). The establishment and productivity of maize is limited due to moisture stress (Rana et al., 2006). For this, maize is suitable alternative crops to replace rice in the *kharif* (rainy) season. It is grown in an area of 9.5 million hectares with 24.5 million tonnes annual production. The adaptability of maize to diverse agro-ecologies and seasons is unmatched to any other crop. So, it can ensure food and nutritional security (Das et al., 2018).

Water shortages are an important factor limiting grain and fruit production like citrus (Kumar et al., 2020; Kumar et al., 2021) in many parts of the world (Dong et al., 2011). Shortage of water resources has become a global problem limiting agricultural development (Wang et al., 2016; Qin et al., 2015). In semi-arid areas, it is desirable to maximize the benefits of the limited rainfall which occurs by increasing water use efficiency (WUE) of millet (Deng et al., 2006; Fang et al., 2010). Mulching is one of the most efficient methods of improving WUE and grain yield of crops (Han et al., 2004). Plastic mulching increases topsoil temperature and prolong reproductive growth, with these aspects positively associated with grain yield (Qin et al., 2014). The practice of using plastic mulch, conventional water management will lead to an increase in soil moisture and prevent fertilizer leaching (Pahlevani et al., 2021). Crop production in the dryland region is constrained by water deficiency, and soil erosion caused by wind and/or water. Adoption of no tillage with raised bed system maintained better soil moisture regimes especially during dry spells as compared to those under conventional tillage and flatbed or ridge and furrow method of planting (Yadav et al., 2018). Conventional tillage practices, including intensive soil cultivation and crop residue removal and burning, have exacerbated soil erosion and degradation, thus contributing to the development of soils with low organic matter contents and a fragile physical structure (Tang, 2004). In contrast practices of conservation, tillage improves the soil physical structure and also helps in addition of nutrient by crop residues in soil. This practice improves the soil organic carbon and soil fertility status with climate variability (Wheeler and von Braun, 2013). Hence, water-saving technology maintains soil health and sustainability as well as economically beneficial, needs to be developed (Rao et al., 2019).

In attempts to control the severe erosion and ensure the food security of local people, conservation tillage with mulching has been encouraged as a means of conserving soil and water resources and increasing crop yields (Zhang et al., 2011). It is necessary to evaluate the feasibility of alternative field management practices to guarantee both food security and system sustainability. In this context, we explored and compared the effects of various mulching under conventional tillage, minimum tillage and raised bed furrow sowing on growth, yield and economics of maize crop. Based on the present study, the aim of this experiment is to suggest suitable cultural practices for in situ rain water management for improving productivity, the economics of farmers under dry land condition.

2. MATERIALS AND METHODS

2.1. Site description and experimental design

The field studies were conducted during July to October each year of 2017, 2018 and 2019 at a site on Zonal Research Station, Chianki (24.0130° N, 84.1066° E), Palamu, Jharkhand state, India. The average annual precipitation of the site is 905.9 mm and the soil type is sandy loam having pH 6.7 which comes under order Alfisols. In this experiment, three main plots and four sub-plots under split plot design with three replications. The treatments include CT (Conventional tillage)+no-mulch, CT+farm waste mulch, CT+polythene mulch, CT+soil mulch, MT(Minimum tillage)+no-mulch, MT+farm waste mulch, MT+polythene mulch, MT+soil mulch, RBS (Raised bed sowing)+no-mulch, RBS+farm waste mulch, RBS+polythene mulch, RBS+soil mulch. The size of the plot was 20×20 m^2 separated by a bund of size 60×25 cm^2. The recommended fertilizer dose for maize crop having a variety Rasi-4212 is 120:60:40 (kg ha^{-1}). The maize cultivar was sown on 3rd July, 2017, 3rd July, 2018 and 1st July, 2019 and harvested on 17th October, 2017, 15th October, 2018 and 16th October, 2019.

The plant height was measured from ground level to the flag leaf after full emergence of tassel in the plant. For cob length (cm) dehusked corn from the randomly selected five plants was measured from base to the tip with the help of Vernier caliper and then average value was taken. For the test weight of grains (g), weighted 100 grains from dehusked corn of randomly selected three plants through electronic balance and then averaged. For the measurement of grain yield, dehusked cob of each plot and for measurement of stover yield, whole plant of each plot after harvesting of cob were weighted through electronic balance. For the measurement of rain water use efficiency (kg ha^{-1} mm^{-1}), it is calculated by dividing the grain yield (kg ha^{-1}) to cumulative rainfall (mm) from sowing to harvest. The cumulative rainfall data was taken from meterological center at Zonal Research Station farm, Chianki, Palamu, Jharkhand, India.

The economics for cultivation of maize crops in all the three years was calculated by using cost of cultivation which includes the total expenditure occurred during cultivation period, net return calculated by adding the income obtained by selling of grains and stover and B:C ratio was calculated by dividing the present value of benefits by that of costs and investments.

2.2. Statistical analyses

The effects of the treatments on the measured parameters were evaluated using two-way ANOVA at 5% significance level. All parameters were analysed for variance as for a split plot design considering the three tillage practices as main plot treatments and four mulch practices as sub-plot treatments.

3. RESULTS AND DISCUSSION

3.1. Yield and yield attributing characteristics

3.1.1. Plant height

In first two years i.e. 2017 and 2018, plant height was significantly higher in soil mulch comparison to other mulching methods and among tillage practices, raised bed sowing method showed significantly higher value (Table 1). But in the year 2019, it was shown higher in two treatments i.e. CT+PM and RBS+SM. Raised bed method improved the soil water status and mitigated the effects of waterlogging stress on plant growth (Liu et al., 2010). Plant height and biomass of spring hybrid millet were higher in plastic-mulched than in no-mulch treatments, indicating faster growth in plastic-mulched treatments (Dong et al., 2014).

3.1.2. Cob length and test weight

Plastic mulch in conventional tillage and raised bed sowing, farm waste mulch in minimum tillage shown significantly higher cob length and test weight than the other mulch in every year. Among all mulches, plastic mulch performs better than the others, this might be due to improve moisture content of soil through reduction of evaporation and save water in the root zone (Meskelu et al., 2018). But in case of tillage practices, raised bed sowing method was shown higher cob length and test weight than the others. Conley and John (2013) stated that test weight is an important factor to consider when selecting a variety. Therefore, selecting a variety that has a high test weight potential in any area is critical to maximizing economic gain.

3.1.3. Grain yield and stover yield

Grain yield was shown significantly higher in plastic mulch under all tillage practices in every year but the maximum yield was found in the year 2019 under RBS+PM i.e. 5,169 kg ha^{-1}. Similar result was shown in stover yield and the maximum yield was under RBS+PM i.e. 12,819 kg per hectare in the year 2019. Plastic film mulching is an effective method for increasing crop productivity in dryland agriculture (Wu et al., 2017). Plastic film mulching improved crop nitrogen uptake and increased apparent nitrogen recovery rate and output/input ratio (Hai et al., 2015) due to this crop growth accelerated and conferring higher yield. Relative to non-mulched plots, mulching significantly increased soil temperature and moisture during the early growth stages, increased grain yield by 28.3% and 87.5% respectively (Bu et al., 2013). On the other hand, raised bed sowing method shown higher grain and stover yield among all the tillage methods every year. This might be due to good moisture and thermal regimes condition (Singh et al., 2016) for proper root growth of plants which improves its nutrients uptake. In the year 2017 and 2018, an almost similar result was found. But in year 2019, the yield was 10.68% higher than both the two years. The effect of different types of mulches has been depicted in Figure 1.

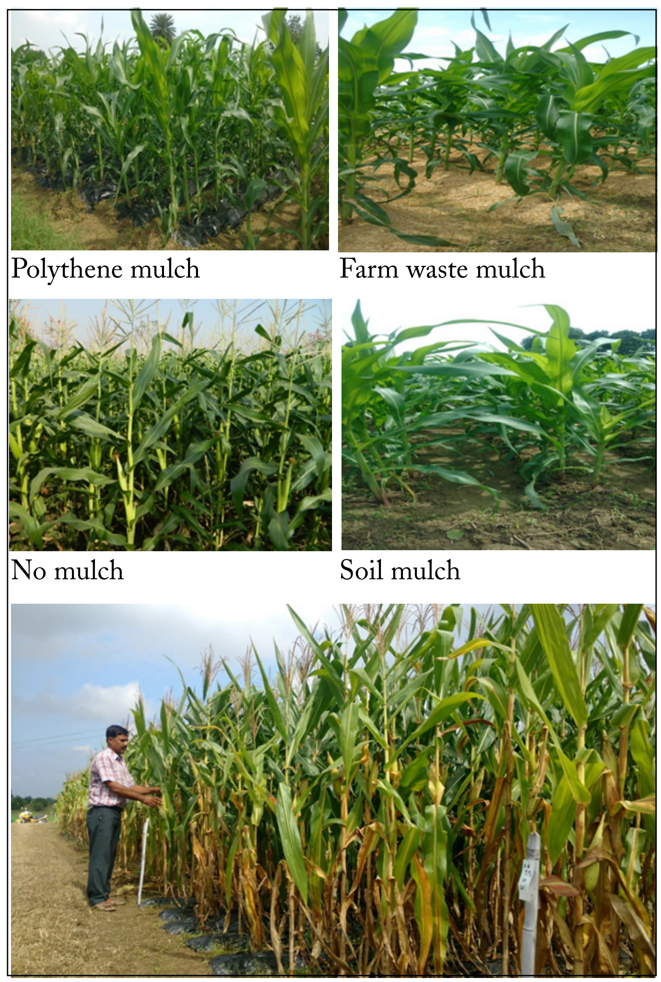

Figure 1: Effect of different types of mulches used in the present study

Year	Treatments	Plant height (cm)	Cob length (cm)	Test weight (g)	Yield (kg ha^{-1})	Stover yield (kg ha^{-1})	RWUE (kg ha^{-1} mm^{-1})	Cost of cultivation (₹ h^{-1})	Net return (₹ ha^{-1})	Net B:C ratio	Weed control (%)
2017	CT+WM	174.4	17.54	20.67	3,014	7,475	3.16	21,500	21,419	1.00	One weeding
	CT+FWM	174.7	16.35	24.33	3,489	8,653	3.65	23,500	26,183	1.11	61
	CT+PM	211.4	21.01	27.17	4,115	10,205	4.31	28,500	30,098	1.06	92
	CT+SM	165.6	19.00	24.67	3,187	7,904	3.34	21,500	23,883	1.11	29
	MT+WM	172.0	15.96	27.17	2,825	7,006	2.96	22,225	18,003	0.81	One weeding
	MT+FWM	205.2	19.33	25.48	3,419	8,479	3.58	24,225	24,462	1.01	57
	MT+PM	188.0	19.07	22.49	4,089	10,141	4.28	29,225	29,002	0.99	90
	MT+SM	208.2	19.27	22.33	3,087	7,656	3.23	22,225	21,734	0.98	25
	RBS+WM	180.0	21.53	20.67	3,154	7,822	3.30	23,000	21,913	0.95	One weeding
	RBS+FWM	207.0	24.07	24.57	4,187	10,384	4.38	25,000	34,623	1.38	66
	RBS+PM	204.3	24.56	25.67	4,525	11,222	4.74	30,000	34,436	1.15	95
	RBS+SM	214.1	23.53	21.73	3,287	8,152	3.44	23,000	23,807	1.04	32
SEm±		0.35: 1.31: 1.60	0.08: 0.19: 0.05	0.21: 0.18: 0.13	0.25: 0.29: 0.25	0.38: 0.50: 0.66					
CD (*p*=0.05) T:M:TxM		1.38: 3.89: 4.74	0.31: 0.57: 0.16	0.83: 0.53: 0.39	0.98: 0.85: 0.74	1.49: 1.49: 1.96					
2018	CT+WM	174.4	17.54	20.67	3,014	7,475	3.24	21,500	21,419	1.00	One weeding
	CT+FWM	174.7	16.35	24.33	3,489	8,653	3.75	23,500	26,183	1.11	61
	CT+PM	211.4	21.01	27.17	4,115	10,205	4.42	28,500	30,098	1.06	92
	CT+SM	165.6	19.00	24.67	3,187	7,904	3.42	21,500	23,883	1.11	29
	MT+WM	172.0	15.96	27.17	2,825	7,006	3.03	22,225	18,003	0.81	One weeding
	MT+FWM	205.2	19.33	25.48	3,419	8,479	3.67	24,225	24,462	1.01	57
	MT+PM	188.0	19.07	22.49	4,089	10,141	4.39	29,225	29,002	0.99	90
	MT+SM	208.2	19.27	22.33	3,087	7,656	3.32	22,225	21,734	0.98	25
	RBS+WM	180.0	21.53	20.67	3,154	7,822	3.39	23,000	21,913	0.95	One weeding
	RBS+FWM	207.0	24.07	24.57	4,187	10,384	4.50	25,000	34,623	1.38	66
	RBS+PM	204.3	24.56	25.67	4,515	11,222	4.85	30,000	34,436	1.15	95
	RBS+SM	214.1	23.53	21.73	3,287	8,152	3.53	23,000	23,807	1.04	32
SEm±		1.02: 1.49: 5:28	0.09: 0.15: 0.05	0.21: 0.15: 0.11	0.23: 0.21: 0.17	0.76: 0.66: 1.25					
CD (*p*=0.05) T:M:TxM		4.02: 4:42: 15.85	0.36: 0.44: 0.14	0.81: 0.44: 0.32	0.91: 0.62: 0.50	3:00: 1.97: 5.20					

Table 1: Effect of tillage and mulching on growth, yield and economics of maize crops

Table 1: Continue...

Year	Treatments	Plant height (cm)	Cob length (cm)	Test weight (g)	Yield (kg ha^{-1})	Stover yield (kg ha^{-1})	RWUE (kg ha^{-1} mm^{-1})	Cost of cultivation (₹ h^{-1})	Net return (₹ ha^{-1})	Net B:C ratio	Weed control (%)
2019	CT+WM	178.3	18.53	21.62	3,527	8,747	3.89	23,500	40,832	1.74	One weeding
	CT+FWM	175.3	17.23	25.43	4,369	10,835	4.82	25,500	54,191	2.13	59
	CT+PM	208.4	22.09	23.31	4,867	12,070	5.37	30,500	58,274	1.91	91
	CT+SM	169.5	19.90	22.62	3,787	9,392	4.18	23,500	45,575	1.94	32
	MT+WM	178.0	17.01	23.63	3,487	8,648	3.85	24,225	39,378	1.63	One weeding
	MT+FWM	204.2	20.32	24.01	4,179	10,364	4.61	26,225	50,000	1.91	53
	MT+PM	178.3	20.03	22.32	4,526	11,224	5.00	31,225	51,329	1.64	88
	MT+SM	207.3	20.31	23.30	3,669	9,099	4.05	24,225	42,698	1.76	23
	RBS+WM	181.2	22.43	21.02	3,738	9,270	4.13	25,000	43,181	1.73	One weeding
	RBS+FWM	208.2	25.09	25.32	4,624	11,468	5.10	27,000	57,342	2.12	62
	RBS+PM	205.3	25.67	26.67	5,169	12,819	5.71	32,000	62,283	1.95	96
	RBS+SM	208.4	24.35	22.38	3,823	9,481	4.22	25,000	44,732	1.79	36
SEm±		1.76: 1.26: 7.71	0.11: 0.19: 0.07	0.15: 0.14: 0.07	0.15: 0.25: 0.13	0.19: 0.74: 0.48					
CD (p=0.05) T:M:TxM		6.93: 3.75: 22.92	0.41: 0.57: 0.21	0.57: 0.41: 0.21	0.60: 0.74: 0.40	0.73: 2.21: 1.43					

3.1.4. Rain water use efficiency (RWUE)

In every year, RWUE was found higher in plastic mulch than the other mulches and among tillage practices, raised bed sowing practice had significantly higher value than the others i.e. 5.71 kg ha^{-1} mm^{-1}. Sharma et al., 2011 reported that polythene mulching showed the highest moisture content followed by straw mulching, soil mulching and lowest in no mulching treatment during both *kharif* and *rabi* seasons. Zhou et al., 2009 showed that soil water content of maize plots with plastic mulch increased 10.5–22.6%. Increment in soil moisture, improve the nutrients status near the root zone for continuous uptake by plants which is beneficial for metabolic activities, growth and development of plants.

3.2. Economics

The net return per hectare (₹ 34,623) and B:C ratio (1.38) of maize production was maximum in RBS+FWM due to the low cost of cultivation in the year 2017 and the same was observed in the year 2018. In the year 2019, out of various treatments, the net return per hectare (₹ 62,283) and stover production (12819 kg ha^{-1}) was found maximum in RBS+ PM than minimum and conventional tillage. Singh et al. (2009) observed that that operational energy and benefit cost ratio were higher in conventional tillage than reduced tillage system in production of maize and wheat. Reduced tillage or no-tillage can lower operation times in the field, thereby, reducing production costs for labor, fuel, machinery, and other equipment while increasing the yield of agricultural production (Fan et al., 2013). From a weed control point of view, raised bed sowing with polythene mulch gave 96% weed control whereas conventional tillage without mulch gave result equal to one complete weeding. The retention of crop residues in ZT inhibited the weed seed germination. The direct contact of sunlight to the upper soil surface is limited when the soil surface is covered with crop residues (Chauhan et al., 2012). Hence, weed seeds lying on the soil surface were withered, dried out, attacked by fungi or subjected to predation by insects and bacteria (Ramesh, 2015). Weeding also increase the cost of cultivation leads to reduce the B:C ratio.

4. CONCLUSION

Among conservation tillage practices, raised bed method with plastic mulch found better in consecutive years i.e. 2018 and 2019. This technique is beneficial and highly cost effective for the farmers. Raised bed prevents the water stagnation condition near the root zone of maize and plastic mulching can improve soil water content, soil temperature and promote the growth and development of maize, thereby significantly increasing yield and WUE at yield levels.

5. REFERENCES

Bi, Y.Y., 1995. China's arable land. Chinese Agricultural Science and Technology Press, (in Chinese), p. 231.

Bu, L.D., Liu, J.L., Zhu, L., Luo, S.S., Chen, X.P., Li, S.Q., Hill, R.L., Zhao, Y., 2013. The effects of mulching on maize growth, yield and water use in a semi-arid region. Agricultural Water Management 123, 71–78.

Chauhan, B.S., Singh, R.G., Mahajan, G., 2012. Ecology and management of weeds under conservation agriculture: a review. Crop Protection 38, 57–65.

Conley, S., John, G., 2013. Top 7 Recommendations for winter wheat establishment, University of Wisconsin agronomy, soybean research, University of Wisconsin-Extension. www.coolbean.info.

Das, T.K., Saharawat, Y.S., Bhattacharyya, R., Sudhishri, S., Bandyopadhyay, K.K., Sharma, A.R., Jat, M.L., 2018. Conservation agriculture effects on crop and water productivity, profitability and soil organic carbon accumulation under a maize-wheat cropping system in the North-western Indo-Gangetic Plains. Field Crops Research 215, 222–231.

Deng, X.P., Shan, L., Zhang, H., Turner, N.C., 2006. Improving agricultural water use efficiency in arid and semiarid areas of China. Agricultural water management 80, 13, 23–40.

Dong, B., Liu, M., Jiang, J., Shi, C., Wang, X., Qiao, Y., Si, F. 2014. Growth, grain yield and water use efficiency of rain-fed spring hybrid millet (*Setaria italica*) in plastic-mulched and unmulched fields. Agricultural Water Management, 143, 93–101.

Dong, B., Shi, L., Shi, C., Qiao, Y., Liu, M., Zhang, Z., 2011. Grain yield and water use efficiency of two types of winter wheat cultivars under different water regimes. Agricultural Water Management, 99(1), 103–110.

Fan, Z., Chai, Q., Huang, G., Yu, A., Huang, P., Yang, C., Liu, H., 2013. Yield and water consumption characteristics of wheat/maize intercropping with reduced tillage in an Oasis region. European Journal of Agronomy 45, 52–58.

Fang, Q.X., Ma, L., Green, T.R., Yu, Q., Wang, T.D., Ahuja, L.R., 2010. Water resources and water use efficiency in the North China Plain: Current status and agronomic management options. Agricultural Water Management 97(8), 1102–1116.

Hai, L., Li, X.G., Liu, X.E., Jiang, X.J., Guo, R.Y., Jing, G.B., Li, F.M., 2015. Plastic mulch stimulates nitrogen mineralization in urea-amended soils in a semiarid environment. Agronomy Journal 107(3), 921–930.

Han, Q.F., Li, X.T., Wang, J.P., Jiang, J., Ding, R.X., Liu, Z.H., Jia, Z.K., 2004. Simulated study on soil moisture of field under water micro-collecting farming conditions. Transactions of the Chinese Society of Agricultural Engineering 20(2), 78–82.

Jat, R.K., Singh, R.G., Kumar, M., Jat, M.L., Parihar, C.M., Bijarniya, D., Gupta, R.K., 2019. Ten years of conservation agriculture in a rice–maize rotation of Eastern Gangetic Plains of India: Yield trends, water productivity and economic profitability. Field Crops Research 232, 1–10.

Khan, S., Hanjra, M. A., Mu, J., 2009. Water management and crop production for food security in China: a review. Agricultural water management 96(3), 349–360.

Kumar, P., Sinha, A., Swapnil, Lata, S., Singh, D., 2021. Standardization of fertilizer application through drip system as compared to conventional method of basin fertigation in Orange. International Journal of Economic Plants 8(1), 025–028. Doi: HTTPS://DOI.ORG/10.23910/2/2021.0408a.

Kumar, S., Kumawat, P., Choudhary, K., 2020. Irrigation scheduling and fertigation in citrus fruit crops. Chemical Science Review and Letters 9(34), 418–424.

Meskelu, E., Tesfaye, H., Debebe, A., Mohammed, M., 2018. Integrated effect of mulching and furrow methods on maize yield and water productivity at koka, Ethiopia. Irrigation and Drainage Systems Engineering 7, 207. doi: 10.4172/2168-9768.1000207

Pahlevani, A., Ebrahimian, H., Abbasi, F., Fujimaki, H., 2021. Distribution of soil water and nitrate in furrow irrigation under different plastic mulch placement conditions for a maize crop: Field and modelling study. International Agrophysics 35(2), 131–144.

Qin, S., Zhang, J., Dai, H., Wang, D., Li, D., 2014. Effect of ridge–furrow and plastic-mulching planting patterns on yield formation and water movement of potato in a semi-arid area. Agricultural Water Management 131, 87–94.

Qin X.L., Zhang F.X., Liu, C., Yu, H., Cao, B.G., Tian, S.Q., Liao, Y.C., Siddique, K.H.M., 2015. Wheat yield improvements in China: past trends and future directions. Field Crops Research 177, 117–124.

Ramesh, K., 2015. Weed problems, ecology, and management options in conservation agriculture: issues and perspectives. Advances in Agronomy 131, 251–303.

Rana, K.S., Shivran, R.K., Kumar, A., 2006. Effect of moisture conservation practices on productivity and water use in maize (*Zea mays* L.) based intercropping systems under rainfed conditions. Indian Journal of Agronomy 51(1), 24–26.

Rao, S.S., Naik, B.B., Ramulu, V., Devi, M.U., Shivani, D., 2019. Impact of irrigation practices on production and water productivity of transplanted rice under NSP canal command area. International Journal of Bio-Resource and Stress Management 10(6), 621-627. DOI : HTTPS://DOI.ORG/10.23910/IJBSM/2019.10.6.2052a.

Sharma, P., Abrol, V., Sharma, R.K., 2011. Impact of tillage and mulch management on economics, energy requirement and crop performance in maize–wheat rotation in rainfed sub humid Inceptisols, India. European Journal of Agronomy 34(1), 46–51.

Singh, J.P. Abrol, V., Hussain, S.Z., 2009. Impact of tillage and nutrient management in maize–wheat crop rotation under dryland cultivation. Agricultural Mechanization in Asia, Africa and Latin America 40(1), 60–160.

Singh, V.K., Dwivedi, B.S., Singh, S.K., Majumdar, K., Jat, M.L., Mishra, R.P., Rani, M., 2016. Soil physical properties, yield trends and economics after five years of conservation agriculture based rice-maize system in north-western India. Soil and Tillage Research, 155, 133–148.

Tang, K.L., 2004. Soil erosion in china. Science and Technology Press (in Chinese), 845.

Verma, S., Shori, A., Kumar, V., Verma, S.K., Singh, J.P., 2020. Response of *kharif* maize under different mulching and integrated nutrient management practices in eastern region of Uttar Pradesh. International Journal of Chemical Studies 8(2), 846–850.

Wang, H., Vicente-Serrano, S.M., Tao, F., Zhang, X., Wang, P., Zhang, C., El Kenawy, A., 2016. Monitoring winter wheat drought threat in Northern China using multiple climate-based drought indices and soil moisture during 2000–2013. Agricultural and Forest Meteorology 228, 1-12.

Wen, X.X., Zhang, D.Q., Liao, Y.C., Jia, Z.K., Ji, S.Q., 2012. Effects of water-collecting and-retaining techniques on photosynthetic rates, yield, and water use efficiency of millet grown in a semiarid region. Journal of Integrative Agriculture 11(7), 1119-1128.

Wheeler, T., von Braun, J., 2013. Climate change impacts on global food security. Science 341, 508–513. https://doi.org/10.1126/science.1239402.

Wu, Y., Huang, F.Y., Jia, Z.K., Ren, X.L., Cai, T., 2017. Response of soil water, temperature, and maize (*Zea mays* L.) production to different plastic film mulching patterns in semi-arid areas of northwest China. Soil & Tillage Research 166, 113–121.

Yadav, G.S., Saha, P., Babu, S., Das, A., Layek, J., Debnath, C., 2018. Effect of no-till and raised-bed planting on soil moisture conservation and productivity of summer maize (*Zea mays*) in Eastern Himalayas. Agricultural Research 7(3), 300–310.

Zhang, S., Li, P., Yang, X., Wang, Z., Chen, X., 2011. Effects of tillage and plastic mulch on soil water, growth and yield of spring-sown maize. Soil and Tillage Research 112, 92–97.

Zhou, L.M., Li, F.M., Jin, S.L., Song, Y.J., 2009. How two ridges and the furrow mulched with plastic film affect soil water, soil temperature and yield of maize on the semiarid Loess Plateau of China. Field Crops Research 13(1), 41–47.