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EFFECTS OF MULCHING AND PLANT SPACING ON GROWTH, YIELD AND QUALITY OF WATERMELON (*Citrullus lanatus*) IN RAPTI RIVERBED, DANG, NEPAL

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ABSTRACT

A field experiment was conducted at Rapti riverbed, Dang, Nepal to study the effects of mulching and plant spacing on growth, yield, and fruit quality of Mastana- a hybrid cultivar of watermelon- during February-May 2019. The two-factor experiment had three types of mulching- black silver polythene, rice straw, and control (no mulch), and three different plants spacing- 2m×1m, 2m×1.5m, and 2m×2m. The experiment was laid out in randomized complete block design with three replications. The result showed both mulching and plant spacing significantly influence growth, yield and quality of watermelon. Considering the mulching materials, the minimum days required for germination (14.44 days), the longest main vine length (316 cm), maximum number of leaves per plant (99.42), the highest individual fruit weight (7.30 kg) and fruit yield mt ha^{-1} (122.1), the maximum TSS and vitamin C content (12.11°B and 18.76 mg/100 g) were recorded from the plants grown under black silver polythene mulch and the lowest values were recorded from the plants grown without mulching except days required to germination and titratable acidity. In case of plant spacing, the higher yield was recorded in 2m×1m plant spacing (140.3 mt ha^{-1}) as compared to 2m×1.5m (95.5 mt ha^{-1}) and 2m×2m (75.2 mt ha^{-1}). Likewise, effect of plant spacing on the number of leaves $plant^{-1}$ was significant in 40 DAS, and 80 DAS. Therefore, Mastana, a hybrid cultivar of watermelon is recommended to grow on black silver polythene with 2m×1m plant spacing in Rapti Riverbed conditions.

Keywords: Mulching, Plant spacing, Quality, Watermelon cv. Mastana

INTRODUCTION

Watermelon is a warm season crop and is grown in all tropical and sub-tropical areas. Watermelon is a wonderful fruit with a high glycemic index (Foster-Powell et al., 2002), enormous antioxidant potential, and low calorific value.

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In Nepal, area under watermelon cultivation has increased in recent years. According to the Statistical Information on Nepalese Agriculture (2016/17), Dang, Bardiya, Gorkha, and Nawalparasi are the major watermelon-growing districts in western Nepal. However, watermelon was grown only in 50 Hectares of land with a production of 910 metric tons in those districts. Among them, Dang constituted the larger area (35 hectares) and higher production (700 metric tons).

Watermelon faces several production constraints like water, light, space, and nutrients due to weeds. Removal of weeds manually, mechanically, or chemically accounts major portion of the pre-harvest cost. An effective method of weed control is manual weeding, but it is tedious and uneconomical due to labor shortage and high wages (Rao and Nagamani, 2010). The productivity of watermelon can be increased through good agricultural practices especially the conservation of moisture and the use of proper plant spacing, nutrient management, and plant protection methods. Cultural techniques for obtaining profitable yields include the usage of polyethylene (PE) mulches (Ban et al., 2009). Other measures such as implementation of plant density strategies and nutrient management have been reported to have a positive impact on watermelon yield (Goreta et al., 2005).

The main objectives of mulching are weed control, soil moisture conservation, and modification of soil temperature (Olsen and Gounder, 2001). Mulching is a non-chemical weed control technique, an effective alternative to herbicides (Awodoyin et al., 2007). The use of different mulching materials, mostly polythene mulches is increasing in vegetable production in Nepal (Jha et al., 2018). Locally available materials like rice straw, rice husk, and dried leaves can also be used to conserve moisture, suppress weeds, and increase yield (Shrestha et al., 2008).

Higher yield in watermelon is also related to dense in-row plant spacing (Huitron-Ramirez et al., 2009). Dense spacing designs may increase competition for water and fertilizers, which results in inadequate vegetative growth and low yields (Knavel, 1988). One of the most important factors in flourishing crop plants is correct spacing because it allows plant to develop to their full potential on top and underneath ground. Adequate space ensures less competition for sunlight, water, and fertilizers. Spacing also prevents the spread of pest and diseases (Celac, 2011). Implementation of plant density strategies and nutrient management have been reported to have a positive impact on watermelon yield (Sabo et al., 2013).

Therefore, proper use of mulches and appropriate plant spacing techniques could increase the yield and quality of watermelon.

MATERIALS AND METHODS

The experiment was conducted in the Rapti riverbed, Dang, Nepal during February-May 2019 to study the effects of mulching and plant spacing on the growth, yield, and quality of watermelon. The experimental site is located at an elevation of 250 meter above sea level in the inner Terai region of Nepal. A randomized complete

block design with nine treatment (Table 1) combinations was used in this study and replicated three times totaling 27 plots. Individual plot size was 48 m^2 (8 m × 6 m).

Table 1. Treatments combination of the experiment field

Treatments	Mulching (m)	Spacing (s)	Treatment combinations	Symbol
T1	No mulch	2 × 1 m	No mulch + 2 × 1 m	M_1S_1
T_2	No mulch	2 × 1.5 m	No mulch + 2 × 1.5 m	M_1S_2
T_3	No mulch	2 × 2 m	No mulch + 2 × 2 m	M_1S_3
T_4	Rice straw	2 × 1 m	Rice straw + 2 × 1 m	M_2S_1
T_5	Rice straw	2 × 1.5 m	Rice straw + 2 × 1.5 m	M_2S_2
T_6	Rice straw	2 × 2 m	Rice straw + 2 × 2 m	M_2S_3
T_7	Black silver polythene	2 × 1 m	Black silver polythene + 2 × 1 m	M_3S_1
T_8	Black silver polythene	2 × 1.5 m	Black silver polythene + 2 × 1.5 m	M_3S_2
T_9	Black silver polythene	2 × 2 m	Black silver polythene + 2 × 2 m	M_3S_3

The experimental field was ploughed 15 days before seed sowing and weeds were removed and the field was levelled. After the layout of the field, 27 plots were prepared. Then pits were made each with dimensions 50cm× 50cm×50 cm and filled with well-mixed FYM and soil. Black silver polythene (30 microns thickness) was kept in the nine plots and a 15 cm thick layer of rice straw was kept in the other nine plots and the remaining nine plots were left open without any mulch cover. Mastana, an F_1 hybrid cultivar of watermelon was selected for the experiment. It is registered and recommended variety to grow in the Terai region of Nepal.

After a week of pit formation and FYM applied, watermelon seeds were sown in pits at a depth of about 2.5 cm. Three seeds were sown per pit for germination assurance. One seedling per pit was maintained at 20 days after germination. Light irrigation was provided immediately after seed sowing. Cultural practices like irrigation, weed management, and pest control were done as per the requirement of the crop. The crop was fertilized at the rate of 10 metric ton farm yard manure, 60 kg urea, 40 kg diammonium phosphate (DAP) and 40 kg muriate of potash (MoP) per hectare (Krishi Diary, 2018). All manure and fertilizers except urea were applied 15 days before seed sowing (DAS). Urea was applied in three equal installments at 20, 40 and 60 DAS.

For data collection, six random plants from each plot were taken during the crop-growing period and after harvesting. Growth parameters; days to germination, length of the main vine (cm), number of leaves, number of lateral branches, and yield parameters; days to flowering, number of fruits, the average weight of fruit (kg), yield (mt ha^{-1}) were recorded during crop growing period and after harvest. After harvest fruit quality attributes; Total Soluble Solids(°Brix), pH, Titrable acidity (%), and Vitamin C (mg $100ml^{-1}$) were also recorded. Data entry and tabulation were done

on MS Excel and data analysis was done using Gen-STAT 18th edition software. The effects of mulching and plant spacing on measured variables were tested with a two-way analysis of variance (ANOVA). The means were compared using DMRT at a 5% level of significance.

RESULTS AND DISCUSSION

Effect of mulching and plant spacing on growth

Early germination was recorded in black silver polythene mulch. The effect of plant spacing on days to germination was non-significant (Table 2). The result showed a non-significant effect on the number of lateral branches within mulching and spacing treatments. However, the result depicted a significant effect in the number of leaves plant^{-1} within mulching treatments. The highest number of leaves plant^{-1} was recorded in black silver polythene as compared to rice straw and control. The effect of plant spacing on the number of leaves plant^{-1} was recorded as significant in 40 DAS, and 80 DAS while, recorded as non-significant in 60 DAS and 100 DAS. The result showed a significant effect on the length of the main vine within mulching treatments. The longest length of the main vine was recorded in black silver polythene mulch. However, a non-significant effect was recorded on the length of the main vine within plant spacing treatments.

The effect of mulching significantly influenced plant growth parameters (days to germination, number of leaves plant^{-1}, and length of the main vine) (Table 3 and 4). The increase in growth parameters was attributed to sufficient soil moisture near the root zone and minimized evaporation loss due to mulching. The extended retention of moisture and its availability also led to higher uptake of nutrients for proper growth and development of plants, resulting in higher growth of plants, as compared to no mulch condition. These findings are similar to the findings of other researchers (Nwokwu and Aniekwe, 2014; Parmer et al., 2013).

Table 2. Effects of mulching and plant spacing on days to germination of watermelon in Rapti riverbed, Dang, Nepal

Treatments	Days to germination
	DAS
Mulching	
Control	16.89[a]
Rice straw	17.44[a]
Black silver polythene	14.44[b]
SEM ±	0.382
$LSD_{0.05}$	1.146*
Plant spacing	

Treatments	Days to germination
	DAS
2 m×1 m	16
2 m×1.5 m	16.78
2 m×2 m	16
SEM ±	0.382
$LSD_{0.05}$	NS
Grand mean	16.26
CV %	7.1

Means with the same letter within a column do not differ significantly at = 0.05 by DMRT. NS- Not–significant, SEM- Standard error of the mean, LSD- Least significant difference, CV- Coefficient of variation

Table 3. Effects of mulching and plant spacing on the number of leaves plant^{-1} of watermelon in Rapti riverbed, Dang, Nepal

Treatments	Number of leaves plant^{-1}			
	DAS			
	40	60	80	100
Mulching				
Control	9.256^{ab}	17.81^{b}	51.88^{b}	75.97^{b}
Rice straw	7.734^{b}	16.5^{b}	69.28^{a}	86.38^{b}
Black silver polythene	9.959^{a}	21.29^{a}	69.68^{a}	99.42^{a}
SEm ±	0.591	0.889	4.13	4.08
$LSD_{0.05}$	1.773*	2.667*	12.39*	12.24**
Plant Spacing				
2 m×1 m	8.104	17.23^{b}	58.03	78.83^{b}
2 m×1.5 m	9.071	17.61^{b}	62.07	87.49^{ab}
2 m×2 m	9.773	20.75^{a}	70.74	95.46^{a}
SEm ±	0.591	0.889	4.13	4.08
$LSD_{0.05}$	NS	2.667*	NS	12.24*
Grand mean	8.98	18.53	63.6	87.3
CV %	19.8	14.4	19.5	14

Means with same letter within column do not differ significantly at p = 0.05 by DMRT. * =Significant at 5% ($p \leq 0.05$), NS- Non –significant, SEM- Standard error of mean, LSD- Least significant effect, CV- Coefficient of variation

Table 4. Effects of mulching and plant spacing on the length of the main vine of watermelon in Rapti riverbed, Dang, Nepal.

Treatments	Length of the main vine (cm)			
	DAS			
	40	60	80	100
Mulching				
Control	18.39[b]	72.17[b]	210.7[b]	254.7[b]
Rice straw	22.74a[b]	74.7[b]	222.4[b]	276.3[b]
Black silver polythene	24.58[a]	94.36[a]	264.2[a]	316[a]
SEM ±	1.455	4.95	9.55	9.78
$LSD_{0.05}$	4.361*	14.84*	28.64*	29.33**
Plant spacing				
2 m×1 m	20.25	75.14	223.7	274.6
2 m×1.5 m	22.51	86.8	231.5	282.7
2 m×2 m	22.96	79.29	242.2	289.7
SEM ±	1.455	4.95	9.55	9.78
$LSD_{0.05}$	NS	NS	NS	NS
Grand mean	21.91	80.4	232.5	282.3
CV %	19.9	18.5	12.3	10.4

Means with same letter within column do not differ significantly at p = 0.05 by DMRT. *= Significant at 5% ($p \leq 0.05$), ** = Significant at 1% ($p \leq 0.01$), NS = Not significant, SEM= Standard error of mean, LSD= Least significant difference, CV= Coefficient of variation

Effect of mulching and plant spacing on yield

The study showed earlier flowering in black silver polythene mulch (66.22 days) as compared to that in rice straw (71.78 days) and control (73 days). In addition, 50 % and 100 % flowering occurred earlier in black silver polythene (77.89 days) followed by rice straw (85.89 days) and control (88.89 days) (Table 5).

Fruit yield (122.1 mt ha^{-1}), number of fruits (4.81), and the average weight of fruit (7.30) were recorded higher in black silver polythene followed by rice straw and the least in the control. Moreover, the higher yield was recorded in 2 m × 1 m plant spacing (140.3 mt $ha^{-1)}$ as compared to 2 m × 1.5 m (95.5 mt ha^{-1}) and 2 m × 2 m (75.2 mt ha^{-1}) plant spacing (Table 6).

The black silver polythene mulch proved its superiority by increasing the fruit yield over rice straw and no mulch. These results substantiate the findings of Ekinci and Dursun, (2009). It appears that black silver polyethylene mulch might have induced

favorable microclimatic and geothermal conditions conducive to the attainment of fruits with higher weight. The above results agreed with those of Arancibia and Motsenbocker (2008). Polyethylene mulch increased yields at all in-row spacing. Its effects on fruit number and yield ha^{-1} were greater at the closer spacing i.e., plant spacing 2 m×1 m. So, according to the experiment conducted closer plant spacing is recommended for watermelons on the riverbed of plains, as long as water and nutrients are not limited and these results are in general agreement with past work with watermelons (Sanders et al., 1999).

Plants under black silver polythene produced larger fruit and higher fruit yield per vine because of better plant growth due to a favorable hydro-thermal regime of soil and a completely weed-free environment. The above results agreed with those of Cenobio et al. (2007) and Arancibia and Motsenbocker (2008). Black silver polythene mulch significantly increased the average weight of fruit. It may due to higher moisture content under mulch that resulted in favorable climatic conditions for fruit development. Another reason may be due to insect repellent action and suppressed weed growth which could enhance fruit development which is in consonance with Moe et al. (2018).

Plants under black silver polythene gave the highest fruit yield followed by rice straw while least at control. The results agreed with that of Dean et al., (2004). They stated that the total fruit yield was significantly higher in mulched plants, especially in silver polythene mulch. Maughan and Drost (2016) also stated that silver-reflective plastic mulches are very effective in reducing aphids and thrips populations. The microclimatic condition around the plant would be greatly influenced by mulches and that can provide favorable temperature and moisture for crop growth and yield. In this study black silver polythene mulch produced larger fruit and higher fruit yield. It can be assumed that the application of mulch on the soil surface can support the favorable microclimatic condition (i.e., soil moisture and soil temperature for fruit development to attain higher total fruit yield). Early flowering and fruit formation were first observed on the plastic mulch as compared to rice straw and control. This is in agreement with Bonanno and Lamont (1987).

Table 5. Effects of mulching and plant spacing on days to flowering of watermelon in Rapti riverbed, Dang, Nepal.

Treatments	Days to flowering		
	Initial flowering	50% flowering	100% flowering
Mulching			
Control	73[a]	78[a]	88.89[a]
Rice straw	71.78[a]	79.22[a]	85.89[a]
Black silver polythene	66.22[b]	70.89[b]	77.89[b]
SEm ±	1.319	1.9	2.01

Treatments	Days to flowering		
	Initial flowering	50% flowering	100% flowering
$LSD_{0.05}$	3.954*	5.69*	6.03**
Plant Spacing			
2 m×1 m	69.44	75	84
2 m×1.5 m	72.56	79.33	87.11
2 m×2 m	69	73.78	81.56
SEm ±	1.319	1.9	2.01
$LSD_{0.05}$	NS	NS	NS
Grand mean	70.33	76	84.2
CV%	5.6	7.5	7.2

Means with same letter within column do not differ significantly at p= 0.05 by DMRT. *=Significant at 5% (p≤0.05), **=Significant at 1% (p≤0.01), NS- Non –significant, SEM- Standard error of mean, LSD- Least significant effect, CV- Coefficient of variance

Table 6. Effects of mulching and plant spacing on the number of fruits, the average weight of fruit, and yield of watermelon in Rapti riverbed, Dang, Nepal.

Treatments	Number of fruits	The average weight of fruit(kg)	Yield (mt ha^{-1})
Mulching			
Control	4.31^{b}	6.252^{b}	91.8^{b}
Rice straw	4.477^{ab}	6.312^{b}	97^{b}
Black silver polythene	4.811^{a}	7.302^{a}	122.1^{a}
SEm ±	0.1282	0.287	5.93
$LSD_{0.05}$	0.3842*	0.861*	17.79**
Plant Spacing			
2 m×1 m	4.533	6.416	140.3^{a}
2 m×1.5 m	4.569	6.527	95.5^{b}
2 m×2 m	4.496	6.924	75.2^{c}
SEm ±	0.1282	0.287	5.93
$LSD_{0.05}$	NS	NS	17.79***
Grand mean	4.533	6.62	103.6
CV %	8.5	13	17.2

Means with same letter within column do not differ significantly at p= 0.05 by DMRT. *=Significant at 5% (p≤0.05), **=Significant at 1% (p≤0.01), ***=Significant at 0.1% (p≤ 0.001), NS- Non – significant, SEM- Standard error of mean, LSD- Least significant effect, CV- Coefficient of variation

Effect of mulching and plant spacing on Fruit quality

The black silver polythene mulch showed a significant increase in TSS (12.11°B) as compared to the rice straw mulch (11.37°B) and the control (11.39°B). Likewise, plant spacing 2 m × 2 m showed a significant increase in TSS (12.06°B) as compared to 2 m × 1.5 m (11.39°B) and 2 m × 2 m (11.34°B) treatments. However, the result revealed the non-significant effect of mulching and plant spacing, on the pH of fruit within treatments (Table 7). Data showed that higher vitamin- C content was found in black silver polythene mulch (18.86 mg 100 ml^{-1}) as compared to rice straw (15.33 mg $100ml^{-1}$) and control (15.2 mg 100 ml^{-1}). While the vitamin- C content of fruit was found non-significant within spacing treatments. The lower amount of TA 0.11 % was recorded in black silver polythene mulch. Higher TA content was found within treatments of rice straw mulch and control (0.13%). Plant spacing showed a non-significant effect on the TA content of fruit.

Maximum TSS, and Vitamin C were observed in black silver polythene. While the minimum TSS was observed on rice straw and a low amount of Vitamin C of watermelon fruit was observed in the control. TA was recorded higher in control followed by rice straw mulch while recorded least in black silver polythene. The present findings were in close confirmation with (Parmar et al., 2013). Fruit in black silver polythene showed the lowest TA with the highest Brix %. It can be assumed that the decrease in TA content of fruits is due to the conversion of the malic acid to sugar level and lycopene biosynthesis and also the polythene mulch can absorb and maintain high temperatures which might improve the sugar level or Brix % of watermelon (Moe et al., 2018). Plastic mulches concentrate carbon dioxide around the plant canopy as the planting holes act as vents for carbon dioxide escaping from beneath the mulch. This relatively elevated carbon dioxide concentration that might have accounted for the increased TSS. On the other side, the improvement in vitamin C, and total sugar in fruits according to polyethylene treatments may be due to the promotion effect in plant growth and metabolic process, which is reflected in increasing chemical composition which is in agreement with (Helaly et al., 2017). Among all the treatments of mulching, minimum acidity was observed in silver on black mulch and the finding agreed with Aruna (2007) in tomato.

Table 7. Effects of mulching and plant spacing on fruit quality of watermelon in Rapti riverbed, Dang, Nepal.

Treatments	TSS(°B)	pH	Vitamin C(mg/100ml)	TA (%)
Mulching				
Control (No mulch)	11.39^{b}	5.791	15.2^{b}	0.1311^{a}
Rice straw mulching	11.37^{b}	5.928	15.33^{b}	0.13^{a}
Black silver polythene	12.11^{a}	5.883	18.76^{a}	0.1189^{b}
SEm ±	0.1479	0.0933	0.653	0.00286

Treatments	TSS(°B)	pH	Vitamin C(mg/100ml)	TA (%)
$LSD_{0.05}$	0.4433**	NS	1.959*	0.00857*
Plant Spacing				
2 m×1 m	11.44[b]	5.806	15.33b	0.13
2 m×1.5 m	11.39[b]	5.956	16.49ab	0.1211
2 m×2 m	12.06[a]	5.841	17.48a	0.1289
SEm ±	0.1479	0.0933	0.653	0.00286
$LSD_{0.05}$	0.4433*	NS	NS	NS
Grand mean	11.63	5.867	16.43	0.1267
CV%	3.8	4.8	11.9	6.8

CONCLUSION

From this study, it is concluded that using black silver polythene as a soil cover increased the vegetative growth, yield, and quality parameters in watermelon, and plant spacing on 2m×1m provided a higher yield. So, for a better yield and fruit quality, it is recommended to grow the Mastana, (a hybrid cultivar of watermelon) on black silver polythene mulch and 2 m row to row and 1 m plant to plant distance.

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