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Improvement of Productivity and Quality of Nepalese Tomato Genotypes Using Black Polyethylene Film as Mulching Material

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to evaluate the effect of black plastic mulch on yield and other associated characters of promising tomato genotypes developed by the National Horticulture Research Centre, Nepal at the Directorate of Agricultural Research, Tarahara, Nepal, during the winter season of 2019. Nine tomato genotypes (HRDTOM 011, HRD 109, HRDTOM 035, HRDTOM 080, HRDTOM 079, HRDTOM 084, HRDTOM 085, HRDTOM 086, and Pusa Ruby as a check) were evaluated in a randomized complete block design (RCBD) with three replications. Genotypes were transplanted 60 cm apart. Analysis of variance showed significant differences for marketable fruits and yield per plant, average fruit weight, total marketable and unmarketable fruit yield, and total fruit yield. Among the tested genotypes, HARDTOM 011 developed the highest (174) number of marketable fruits per plant with the lowest (12.92 g) individual average fruit weight. In contrast, HRDTOM 080 produced the lowest (36) number of marketable fruits per plant with the highest

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(49.70 g) individual fruit weight. HRD 109 and Pusa Ruby provided the highest (69.74 t ha^{-1}) and the lowest (38.51 t ha^{-1}) marketable fruit yields, respectively. The highest total fruit yield was also obtained from the HRD 109. Similarly, HRDTOM 085 and HRDTOM 035 had the highest total soluble solids and fruit size, respectively. Firmness of the fruit and pH content did not differ among the genotypes. With the same genotypes and location (Tarahara), a 98% greater yield demonstrated that tomato production may be significantly boosted with the use of polyethylene film as a mulching medium in winter tomato production in Nepal.

Keywords: Genotypes; plastic mulch; polyethylene; quality; tomato.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the major commercial vegetable crops of Nepal. It is successfully cultivated in the Terai during the winter (September-April) and in the mid- and high-hills during the summer and rainy season (April-November) [1]. Worldwide tomato is produced on 5.03 million hectares where the Asian continent alone covers around 52% of it [2]. As compared to world statistics, Nepal shares only 0.44% of land with 0.22% of total production. Tomato productivity in Nepal is around 18.01 t ha^{-1}, which is half of global productivity and far less than that of Southern Asia [2,3]. Likewise, in 2019, Nepal imported 18,965 tons of tomatoes, which were worth US $258, 7000 [2]. It shows a huge gap between consumption and supply from internal production of tomatoes. Therefore, selection of high yielding tomato genotypes is the major focus of tomato breeding program in Nepal [1].

The major portion of the tomato consumed in the country comes from plains of Nepal [4] where it is a winter season crop [5]. During this season, the market price of the tomato remains low as compared to the summer-rainy season [4]. Besides being a main season, tomato farmers in winter get less economic benefit due to lower production from existing tomato genotypes. Breeding for high-yield potential genotypes of tomatoes or imposing management practices that can increase the yield of existing varieties are the only available options for commercial tomato production. Many researches in the past have established that the management practice significantly increase the tomato yield. Significantly high tomato yield in winter season was produced with black plastic mulch as compared to the non-mulched condition in the plains of Nepal [5].

It is normal practice to apply plastic mulch to promote the development and yield of the crop. In vegetable production, black plastic mulch is frequently used for a variety of purposes, such as insect control and weed suppression by obstructing light needed by weed seed [6]. However, its significant use is to increase soil temperature in winter season. Moreover, black plastic film mulch significantly increases topsoil temperature as compared to open field control, and it also conserves more water as long as 40 days after planting [7], [8] reported the topsoil temperature differences between black plastic mulch and bare soil were 2.2 to 3.4°C. They also reported 20.7 to 29.8% increase in tomato yield with black plastic mulch compared to bare soil. Additionally, tomato fruit quality has also been improved by the use of black plastic mulch [9]. Therefore, it was worthy to evaluate the effect of black polyethylene mulch on yield and quality attributes of promising tomato genotypes developed by the National Horticulture Research Centre (NHRC), Nepal.

2. MATERIALS AND METHODS

2.1 Site of Experiment

The experiment was conducted on the farm of Directorate of Agricultural Research, Tarahara, which is located at 26º42'16.85" North latitude and 87º16'38.43" East longitude and 136 meters above sea level in the eastern part of Nepal in Province No. 1 (Fig. 1). It is a sub-tropical zone with warm climatic conditions. The majority of the area is under irrigated condition. The soil texture of the whole farm land is dominated by clay loam with sandy loam to loam varying with the distribution of land within the farm. The pH of the soil ranged from 6.5 to 7.0 which indicates a slightly acidic to neutral status of the soil.

2.2 Experimental Design and Data Analysis

Promising open pollinated tomato genotypes developed at National Horticulture Research Centre (NHRC), Khumaltar, Nepal were used for this experiment. Nine tomato genotypes (HRDTOM 011, HRD 109, HRDTOM 035, HRDTOM 080, HRDTOM 079, HRDTOM 084,

HRDTOM 085, HRDTOM 086) including Pusa Ruby as check were evaluated at DoAR, Tarahara using black plastic film as a mulching material. The experiment was laid out in a Randomized Complete Block Design (RCBD). The seeding was done in October 2019 and 21 days old seedlings were transplanted at the pre-perforated hole (5 cm diameter) on plastic sheets in the field with a spacing of 60 x 60 cm with three replications. Before transplanting raised beds of 90 cm wide were prepared and covered with black/silver plastic mulch keeping black side up. The black plastic film of 50-micron thickness was used in this study. The standard recommended dose of fertilizers (150:120:100 NPK kg ha^{-1} + 15 ton FYM ha^{-1}) was applied. Morphological (plant height, number of branches and number of leaves per plant) and yield attributing (average fruit weight, yield per plant, marketable fruits per plant) characters were recorded. For quality parameters, fruits were sampled at light red stage to analyze quality traits. Fruit juice was extracted by crushing tomato fruit pulps and digital refractometer was used for measuring total soluble solids (TSS) and expressed in °Brix. pH of the fruit juice was determined by using pH meter. Diameter and pericarp thickness were measured with digital vernier caliper. Fruit firmness was measured with penetrometer (FACCHINI, FT-011, Italy).

All observed data was subjected to analysis of variance (ANOVA) using RStudio software (the "Agricolae" package), and treatment means were compared by Duncan's Multiple Range Test (DMRT) at a 5% level of significance. ArcGIS (10.3) and SigmaPlot (12.0) versions were used to create Fig. 1 and Fig. 2, respectively. The result of this experiment was compared with the result obtained by NHRC at the same location (Tarahara) with the same genotypes in no-mulch condition. In discussion, the result obtained by NHRC in multi-location experiments within national research system also utilized.

3. RESULTS

3.1 Morphological Parameters

The major morphological characters i.e., plant height, branches and leaves per plant differed significantly among tomato genotypes (Fig. 2). The tallest genotype was HRDTOM 079 from transplanting to the growth period up to 45 days after transplanting (DAT). The tallest genotype was ultimately determined to be HRD 109 (170.07 cm), which displayed a faster rate of growth at final harvest. HRDTOM 084 had the highest number of branches per plant (18.40) at 60 DAT which differed statistically with the others except HRDTOM 086 (17.07). In general, genotypes with dwarf stature had more branches. HRDTOM 084 also had the highest number of leaves per plant. This study showed the number of leaves in a tomato plant increased with the increased number of branches.

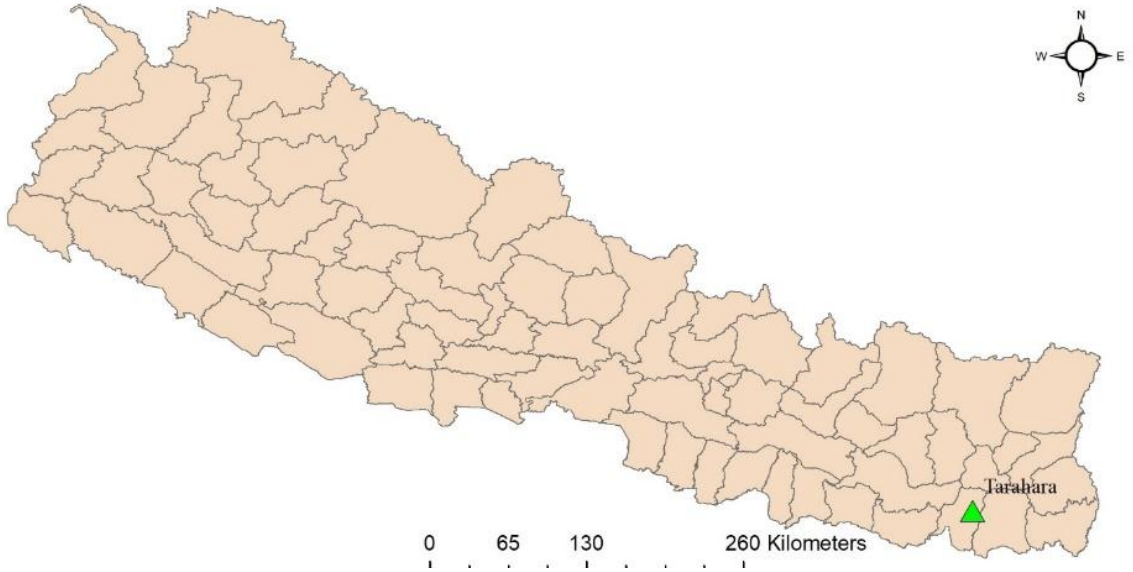

Fig. 1. Location of the experiment site in Nepal

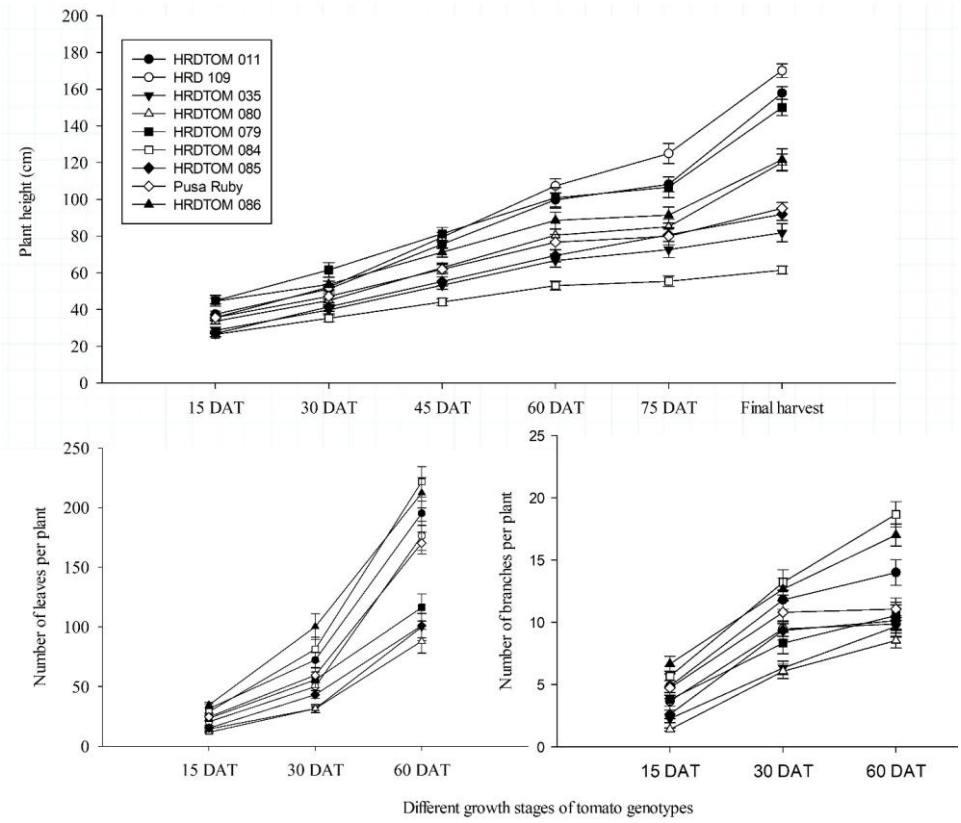

Fig. 2. Effect of plastic mulch on major morphological characters of tomato genotypes

3.2 Yield and Yield attributing characters with plastic mulch

Tomato genotypes differed statistically for yield and yield attributing characters (Table 1). Fruit yield per plant ranged from 1.84 to 2.73 kg. The highest fruit yield per plant (2.73 kg) was recorded from HRD 109. The highest number of marketable fruits per plant (174) were obtained from HRDTOM 011. Likewise, the highest marketable yield (69.74 t ha^{-1}) was recorded from HRD 109. The average weight of individual fruit ranged from 12.92 to 49.70 g. HRDTOM 011 and HRDTOM 080 had the smallest and largest fruit, respectively.

3.3 Yield and Yield Attributing Characters without Plastic Mulch

The results showed the significant difference on plant height, days to 50% flowering, number of fruits per plant, average fruit weight and fruit yield. The tallest plant was HRD 109 (124 cm) followed by HRDTOM 011 (108 cm) whereas the shortest plant was HRDTM084 (56 cm). HRD 109 and HRDTOM 086 flowered earlier (28 days) whereas HRDTOM 079 reached flowering stage late (38 days). The number of fruits per plant was the highest in HRD 109 (38) followed by HRDTOM 085 (35). Likewise, the highest yield (45.3 t ha^{-1}) was obtained from HRDTOM 085 followed by HRDTOM 035 (39.5 t ha^{-1}) (Table 2). Fruit weight ranged from 19.4 (HRDTOM 011) to 57 g (HRDTOM 085).

3.4 Effect of Plastic much on Fruit Quality of Tomato Genotypes

Fruit physico-chemical properties (total soluble solids, pH, fruit firmness, and pericarp thickness) differed statistically among tomato genotypes (Table 3). Total soluble solids (TSS) content observed in tomato genotypes varied between 4.10 - 5.63 ºBrix. HRDTOM 085 had the highest amount of TSS which was at par with HRDTOM 086, Pusa Ruby, HRDTOM 079 and HRD 109. The sourness of the fruits, measured as pH value, was in the range of 4.17 to 4.42 across the genotypes. Though genotypes were non-significant for pH, the highest pH value was recorded on HRDTOM 085. Fruit firmness and pericarp thickness were interrelated. The highest pericarp thickness was recorded on HRDTOM 080. Fruits of this genotype had more firmed fruit though firmness of fruit did not differ statistically.

Table 1. Yield and yield attributing characters of tomato genotypes cultivated using black polyethylene film as mulching material

Genotypes	Fruit yield per plant (kg)	Marketable fruits per plant	Marketable yield (t ha^{-1})	Unmarketable yield (t ha^{-1})	Total yield (t ha^{-1})	Average fruit weight (g)
HRDTOM 011	2.45^{bc}	174^{a}	62.54^{b}	6.05^{cd}	68.59^{bc}	12.92^{e}
HRD 109	2.73^{a}	134^{b}	69.74^{a}	6.14^{cd}	75.88^{a}	18.71^{cde}
HRDTOM 035	2.22^{def}	46^{d}	52.08^{c}	9.41^{bc}	61.49^{def}	40.67^{b}
HRDTOM 080	2.10^{ef}	36^{d}	48.26^{cd}	9.76^{bc}	58.02^{ef}	49.70^{a}
HRDTOM O79	2.27^{cde}	98^{c}	58.83^{b}	4.12^{d}	62.95^{cde}	21.79^{cd}
HRDTOM 084	2.45^{bcd}	69^{cd}	46.59^{cd}	21.40^{a}	67.99^{bcd}	24.47^{c}
HRDTOM 085	2.01^{fg}	42^{d}	44.71^{d}	10.86^{bc}	55.57^{fg}	38.96^{b}
HRDTOM 086	2.61^{ab}	172^{a}	63.70^{b}	8.80^{bcd}	72.50^{ab}	14.13^{de}
Pusa Ruby	1.84^{g}	53^{d}	38.51^{e}	12.51^{b}	51.02^{g}	26.51^{c}
Mean	2.30	92	53.88	9.89	63.78	27.54
F-test	***	***	***	***	***	***
LSD (≤0.05)	0.25	34.52	5.55	5.28	6.83	8.83
CV (%)	6.18	21.75	5.95	30.87	6.18	18.52

*In the columns means followed by the same letter are not significantly different (P≤0.05) by DMRT. Significance level for ANOVA: *** P ≤ 0.001*

Table 2. Performance of tomato genotypes without plastic mulch at DoAR, Tarahara

Genotypes	Plant height (cm)	Fruits per plant	Individual fruit weight (g)	Yield (t ha^{-1})
HRDTOM 011	108	27	19.4	12.4
HRD 109	124	38	27.0	25.5
HRDTOM 035	73	28	55.2	39.5
HRDTOM 080	85	8	45.8	11.2
HRDTOM O79	107	3	42.0	3.7
HRDTOM 084	56	25	26.9	11.9
HRDTOM 085	80	35	57.0	45.3
HRDTOM 086	91	32	23.1	16.9
Pusa Ruby	80	22	35.3	20.4
F-test	**	**	**	**
LSD (≤0.05)	19.23	17.97	10.29	16.87
CV (%)	12.40	42.80	16.10	46.90

*Source: NHRC, 2020. Significance level for ANOVA: ** P ≤ 0.01*

Table 3. Physico-chemical properties of tomato genotypes under plastic mulching condition

Genotypes	TSS (^{o}Brix)	pH	Diameter (mm)	Firmness kg/cm^2	Pericarp thickness (mm)
HRDTOM 011	4.73^{b}	4.32	30.47^{ef}	2.55	3.9^{c}
HRD 109	5.06^{ab}	4.34	40.48^{bc}	3.06	5.67^{b}
HRDTOM 035	4.86^{b}	4.17	49.36^{a}	3.48	7.19^{a}
HRDTOM 080	4.66^{bc}	4.19	36.52^{cde}	2.13	4.66^{bc}
HRDTOM 079	5.06^{ab}	4.34	31.78^{def}	2.4	4.29^{bc}
HRDTOM 084	4.10^{c}	4.39	37.60^{cd}	3.39	4.58^{bc}
HRDTOM 085	5.63^{a}	4.42	44.58^{ab}	3.16	5.49^{b}
HRDTOM 086	5.50^{a}	4.17	29.71^{f}	2.1	3.23^{c}
Pusa Ruby	5.23^{ab}	4.22	31.57^{def}	2.36	3.41^{c}
Mean	4.98	4.28	36.9	2.74	4.71
F-test	**	NS	***	NS	**
LSD (≤0.05)	0.59	1.2	6.12	1.38	1.52
CV (%)	6.83	6.2	9.58	15.2	9.87

*TSS = total soluble solids. In the columns means followed by the same letter are not significantly different (P≤0.05) by DMRT. Significance level for ANOVA: ** P ≤ 0.001, *** P ≤ 0.001, NS = Non significant*

4. DISCUSSION

Tomato morphological traits and yield-related characteristics are a result of interactions between genotype and environment. The tested genotypes have shown variation in these traits over the locations. With plastic mulch, HRD 109 (124 cm) grow tallest, the similar characteristics of this genotype was observed under non-mulched condition at Tarahara (136 m) and Lumle (1740 m) in different altitude [1], however, these genotypes did not showed statistical difference in Khumaltar (1335 m). The difference in morphological characters of tomato genotypes in different locations have been reported by different researchers [10,11]. Among the important yield attributing characters, average fruit weight of the genotypes also varied statistically with or without plastic mulch. The highest number of fruits per plant was recorded in HRDTOM 011 (174 per plant) which also had the smallest fruits. Generally, in tomato, number of fruits and fruit weight are inversely related. Similar characteristics was also observed at Tarahara and Lumle [1]. Similar kinds of results have also been reported by [4] from the plains of Nepal. In this study, the highest fruit yield was obtained from HRD 109 (69.74 t ha^{-1}) and same genotypes also provided the highest yield at Lumle (51 t ha^{-1}) and Khumaltar (24.91 t ha^{-1}) with no-mulch condition [1]. Moreover, HRD 109 produced high yield at Tarahara with black plastic much as compared to no mulch condition (25.50 t ha^{-1}). A study conducted by [12] discovered that tomato varieties respond differently to plastic mulch. They recorded significantly high yields of tomato varieties Arka Raksha (53.3 t ha^{-1}) and Rocky (37.2 t ha^{-1}) with black plastic mulch, as compared to 47.74 t ha^{-1} and 32.21 t ha^{-1}, respectively, under no mulch

condition. The difference in yield of tomato genotypes could be attributed to genotype and management interaction. However, the mean yield of these genotypes at Lumle (36.76 t ha^{-1}), Tarahara (27.25 t ha^{-1}) and Khumaltar (18.90 t ha^{-1}) without plastic mulch and at Tarahara with plastic mulch (53.88 t ha^{-1}) clearly indicated that tomato yield can be increased substantially with use of polyethylene film as a mulching material in winter season tomato production in Nepal.

Genotype and growing condition determine the quality of the fruit. The significant difference among tomato genotypes for quality traits could be attributed to their genetic makeup and the influence of the plastic mulch. In this study, sugar content, measured as the total soluble solids (TSS), ranged from 4.10 - 5.63 ºBrix among tomato genotypes. It is one of the main components in tomato flavor and influences consumer preferences and industrial performance [13]. Moreover, it is reported as a beneficial indicator for tomato taste [14]. In general, it ranged from 4 to 6 °Brix in tomato fruits of different genotypes and the tested genotypes are within that range. Pericarp thickness is another important trait that determines shipping quality of tomato fruits. The difference among genotypes for this character is in agreement with [4]. Pericarp thickness is highly correlated with fruit firmness. It improves the mechanical properties of fruit that better tolerates transportation and storage. In addition, it is an important fruit quality trait in tomato that needs to be improved so fruits are more attractive to consumers [15]. However, [9] found a non-significant effect on tomato fruit firmness between the plastic mulch and no-mulch conditions. A potential genotype for commercial cultivation for fresh consumption, storage, and industrial application is identified among the examined genotypes as HRD 109, which has a greater level of TSS (5.06 oBrix), a thick pericarp, and the best marketable yield.

5. CONCLUSION

This study clearly suggests that black plastic mulching is superior to no-mulch conditions for increasing tomato yield during the winter season in Nepal. Some of the promising genotypes developed by NRHC showed encouraging results with plastic mulching too. HRD 109 was identified as one of the promising tomato genotypes in Nepal for commercial production, irrespective of mulching with black polyethylene film. Its performance across the wide agro-ecological zones (plain to upper-mid hills) demonstrated wider climatic adaptation. Identification of a genotype with the highest yield, along with a higher TSS and a thick pericarp, is the key achievement of this experiment. The study's limitation is the lack of direct analysis of the effect of mulch and no-mulch conditions on tomato genotypes. However, based on the results obtained, HRD 109 can be considered for release as a variety to take advantage of by contributing to the improved livelihood of tomato growers in Nepal.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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