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Yield and Grading of Potato (*Solanum tuberosum* L.) as Influenced by Different Mulch Materials

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ABSTRACT

Mulch prevents moisture loss, maintains soil temperature, suppresses weed growth, facilitates microbial growth, prevents soil erosion and compaction; thus, maintains soil fertility. Mulching is recommended in potato production for its soil moisture conservation potentiality. In general, organic mulches like water hyacinth, rice straw, wheat straw and rice husk are widely used as mulch material in potato production. To explore the consequences of using various mulch materials on potato, particularly in yield and grading an experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka. Five potato varieties viz., Asterix, Lady rosetta, Courage, Diamant and BARI TPS-1 were considered and different treatments were no mulch, water hyacinth, rice straw and rice husk. Randomized complete block design (RCBD) was used to design the experiment and three replications was done to maintain better estimation. Tuber yield and tuber size were measured after harvesting and then grading was done according to the sizes to compare the variations among the treatments. Different potato varieties and/or mulch materials was seen to generate a significant change on maximum yield and quality contributing parameters like marketable yield, seed potato, french fry and chips potato in field condition. Diamant produced the highest amount of tuber, marketable and seed potato yield over other five varieties. On the other hand, Courage showed the highest non-marketable and non-seed tuber production while giving a good amount of chips potato comparing other varieties. Rice straw showed the best performance among the three mulch materials, when comparing tuber yield, marketable yield and seed potato, as opposed to no mulch condition performed better in chips potato production only.

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1. Introduction

Worldwide, potato (*Solanum tuberosum* L.) is one of the most used vegetables. Now, potato is grown in over 160 countries, considered as one of the four major agronomic crops (after wheat, maize and rice) all over the world as a staple food (Zarzecka *et al.*, 2020) with its 388.2 million tons of annual production (FAOSTAT, 2018). The essential elements for bodybuilding like carbohydrate, protein, vitamins, calcium and phosphorus are present in potato. Moreover, it is the richest source of calories that are needed for the daily output of human energy (Duhlian *et al.*, 2018). Consumption of potato can be possible in multiple forms like boiled, fried and/or in processed forms like chips, french fry, powder, potato papad, etc. In developing countries, potato production is about 30% of the world's potato production and it is increasing day by day. Gradually, it is taking an important part in uplifting rural employment and income source for the expanding demography (Wailare *et al.*, 2019). Bangladesh ranked the seventh position in the world for potato production and in Bangladesh, potato is in the second position after rice (FAOSTAT, 2018). In Bangladesh potato is used as vegetable all year round

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and becoming more popular for its multifarious ways of consumption including the processed ones. For this objective, potato quality is also becoming an important fact to be concerned beside its yield. Grading system is a convenient approach for properties determination and marketing risk minimization that can be done easily to sort out the quality tuber for direct or processed consumption (Sharkar *et al*., 2019). However, both the yield and quality of potato are not up to the mark in Bangladesh yet. It may be due to the genetic makeup of the available varieties, existing environment, nutrient stress and cultivation process (Kumar *et al*., 2003; Marwaha *et al*., 2010). Besides, potato is sensitive to water stress, which can significantly reduce yield even in short time exposure. Deficit of irrigation water is one of the main constraints in the world as well as in Bangladesh and it becomes severe during dry winter season. As the consequence of groundwater table declining and surface water resources drying, our crop production is greatly being hampered by water scarcity during winter season (Sarker *et al*., 2019). As potato is grown as a robi crop in winter, water deficit acts as an important barrier in its production.

Mulching is a process of using organic or inorganic materials in soil surface to protect the soil moisture, inhibiting evaporation loss. Besides manipulating the soil temperature and top soil moisture, mulch material can prolong the reproductive stage of the plant which helps in yield increment (Sharma and Bhardwaj, 2017). If mulch materials are chosen considering the existing climatic conditions and soil status including applied fertilizer doses, it can enhance productivity level and reduce water usage to a great extent (Li *et al*., 2018). Variety is defined as a plant's genetic makeup that can effect stem number, aboveground mass, number of seed plant^{-1} and gradually the yield of the crop (Poštić *et al*., 2017). Being a swallow rooted crop, potato is not good in soil penetration to uptake water (Iwama, 2008) and so it cannot withstand a high level of water depletion condition and needs to be irrigated from time to time (Poddar *et al*., 2018). Mulching can be a useful way to minimize the problem as it can decrease water loss through evaporation, improve water infiltration capacity and help in the distribution of moisture again and solve the water stress condition to some extent (Kumar *et al*., 2018). Moreover, it helps in weed control and nutrient supply. As a consequence, mulch materials act positively in enhancing the quantity and quality of potato production. Despite all this potentiality, mulch materials are not much more used in our country. Hence, our study was done to investigate how mulch materials can bring changes in potato yield and grade among different varieties.

2. Materials and methods

2.1. Experimental location, design and treatments

The experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University. The area was under 23°77΄ N latitude and 90°33΄ E longitude with 8.6 meter altitude sea level. Soil was characterized by silty clay texture with olive-gray color and common fine to medium exclusive dark yellowish-brown mottles was also prominent there. Soil pH was recorded as 5.6 with the presence of 0.45% organic carbon. The experiment comprised of two factors, variety of potato and mulch materials. Five different potato varieties (Asterix, Lady rosetta, Courage, Diamant and BARI TPS-1) and four mulch materials (control, water hyacinth, rice straw and rice husk) were considered. After combining the factors, the experiment consisted of 20 treatment combinations and it was done by following Randomized Complete Block Design (RCBD). There were three replications in the experiment. The single unit of the plot was 4 m × 3 m in size and sprouted seed tubers were used as planting material in each plot. Yield and quality of storage was observed. The data gathered from observations were then analyzed and the dissimilation between means were assessed by the DMRT test.

2.2. Crop husbandry

The experimental plot was added with the recommended dosage of cowdung, urea, triple superphosphate, muriate of potash, gypsum, zinc sulfate, magnesium sulfate and boric acid. Cowdung was applied prior to final land preparation and the gap was about 10 days. The entire dosage of triple superphosphate, gypsum, zinc sulphate, magnesium sulphate, boric acid and 50% of urea was used as basal dose in the time of final land preparation. Side dressing was done with the remaining 50% urea at 35 and 50 days after planting (DAP) and it was done equally at the time of the first two earthing up. Mulches (water hyacinth, rice straw, rice husk) were applied manually @10 ton ha^{-1} after soil preparation. As mulches prevailed over soil surface fully, perforations were made on the mulch to let the potato come off. After seeing 40-50% plant maturity with drying up plant tops, haulm cutting was done. The tuber were harvested after their skin hardening and for this, they were kept under soil for 10 days after haulm destruction. From each plot, potato were harvested individually. Then bagging and tagging were done before taking these potato to the laboratory.

2.3. Data measurement procedures

2.3.1.Tuber yield (t ha^{-1})

Randomly 1 m^2 area of a single plot was chosen and tuber having maturity were collected from it and then measured instantly. To determine the yield of tuber the following calculation was applied (Eq.1)

$$\text{Tuber yield (t ha}^{-1}) = \frac{\text{Yield (kg m}^{-2}) \times 10000\ \text{m}^2}{1000\ \text{kg}} \quad (1)$$

2.3.2.Grading of tuber

Potato that were taken from single plot were separated by number and weight considering the diameter of the potato. The diameter of each sample was recorded using a measurement scale and categorized into the following classes: >55 mm, 45-55 mm, 28-45 mm and <28 mm and converted to percentages. Potato tuber greater the 28 mm were estimated as marketable yield and tuber that range from 28-55 mm were measured as seed tuber. Whereas, chips potato and French fry potato was graded as 55-75 mm and >75 mm, respectively. Undersized tubers i.e., <28 mm and oversized tubers i.e., >55 mm, were graded as a non-seed tuber. For grading, a particular type of frame (square shaped) was used.

2.4. Statistical analysis

MSTAT-C computer package program was used to do statistical analysis of the recorded data. The Least Significant Difference (LSD) at 5% levels of probability was applied to compare the significant differences among the means of treatments (Gomez and Gomez, 1984).

3. Results and discussion

3.1. Tuber yield (t ha^{-1})

Tuber yield was affected by different varieties and mulch materials. Considering the varieties alone, Diamant appeared with the maximum tuber yield (30.58 t ha^{-1}) and Courage with the minimum (24.09 t ha^{-1}) tuber yield (Table 1). Among the mulch materials, rice straw resulted in higher tuber yield over other mulches used and it was true in the case of most of the varieties. However, using no mulch materials was led to the lowest tuber yield in all five experimented varieties.

3.2. Marketable and non-marketable yield (%)

Marketable and non-marketable yield percentage was seen to differ among the varieties and mulch materials. Diamant showed the highest (82.73%) marketable yield, which was seen to be statistically similar with Lady rosetta and Courage showed the lowest (70.9%) marketable yield. A significant variation was also found in the marketable yield affected by various types of mulch materials. The highest marketable yield percentage was observed from rice straw and it showed better performance irrespective of varieties. On the contrary, all of the varieties showed the lowest marketable yield in mulch-free condition.

The more non-marketable yield was in Courage (29.1%) and less was in Diamant (17.27%), which was statistically like Lady Rosetta. When mulch materials were used, the maximum non-marketable yield was found from no mulch over any other mulch materials. All varieties gave less non-marketable yield after using the mulch materials.

3.3. Weight of marketable and non-marketable yield (t ha^{-1})

The weight of marketable yield was greatly changed by different varieties and mulch materials. Results represented that the maximum weight of marketable yield (26.27 t ha^{-1}) was observed in Diamant and the minimum weight of marketable yield (17.76 t ha^{-1}) was found in Courage. In case of mulch materials, rice straw showed the highest weight of marketable yield and it performed steadily with other varieties also. Using no mulch decreased the weight in all varieties.

Among the five varieties, Courage showed maximum weight of non-marketable yield (6.33 t ha^{-1}) and Diamant showed minimum weight of non-marketable yield (4.31 t ha^{-1}). Non-mulch condition resulted in the highest weight of non-marketable yield comparing the mulch materials used specially over rice straw mulch. This was a common scenario for all varieties (Table 1,2).

Table 1. Yield parameters of potato as influenced by different varieties and mulches in ambient condition

Treatment	Tuber yield (t ha^{-1})	Marketable yield (%)	Non-marketable yield (%)	Weight of marketable yield (t ha^{-1})	Weight of non-marketable yield (t ha^{-1})
Effect of variety					
Asterix	27.69^{c}	78.65^{b}	21.35^{c}	22.30^{c}	5.39^{c}
Lady rosetta	29.68^{b}	81.04^{a}	18.96^{d}	24.77^{b}	4.92^{d}
Courage	24.09^{e}	70.90^{d}	29.10^{a}	17.76^{e}	6.33a
Diamant	30.58^{a}	82.73^{a}	17.27^{d}	26.27^{a}	4.31^{e}
BARI TPS-1	26.39^{d}	74.75^{c}	25.26^{b}	20.43^{d}	5.96^{b}
$LSD_{0.05}$	0.86	1.81	1.75	0.67	0.24
CV(%)	10.60	10.49	8.36	7.31	8.32
Effect of mulching					
Control	22.49^{d}	65.64^{c}	34.36^{a}	15.29^{d}	7.20^{a}
Water hyacinth	29.40^{b}	81.57^{b}	18.43^{b}	24.66^{b}	4.74^{c}
Rice straw	30.45^{a}	83.06^{a}	16.94^{c}	25.90^{a}	4.55^{c}
Rice husk	28.41^{c}	80.18^{b}	19.82^{b}	23.38^{c}	5.04^{b}
$LSD_{0.05}$	0.92	2.02	1.43	0.54	0.23
CV (%)	10.62	10.49	8.36	7.31	8.32

Different letters in each column indicate a significant difference ($p<0.5$)

Table 2. Yield parameters of potato performed by the combined effect of different varieties and mulches in ambient condition

Treatment	Tuber yield (t ha^{-1})	Marketable yield (%)	Non-marketable yield (%)	Weight of marketable yield (t ha^{-1})	Weight of non-marketable yield (t ha^{-1})
V_1M_1	23.44^{eg}	67.58^{i}	32.42^{c}	16.30^{m}	7.14^{ab}
V_1M_2	28.70^{ae}	81.74^{c}	18.26^{i}	23.73^{g}	4.97^{e}
V_1M_3	30.28^{ad}	83.62^{ab}	16.38^{j}	25.68^{e}	4.60^{e}
V_1M_4	28.35^{ae}	81.66^{c}	18.34^{i}	23.49^{g}	4.86^{e}
V_2M_1	24.48^{dg}	70.18^{h}	29.82^{d}	17.60^{l}	6.88^{b}
V_2M_2	31.30^{ac}	85.04^{a}	14.96^{jk}	27.26^{b}	4.04^{f}
V_2M_3	31.92^{ab}	85.18^{a}	14.82^{jl}	27.87^{b}	4.05^{f}
V_2M_4	31.03^{ad}	83.77^{ab}	16.23^{j}	26.33^{cd}	4.70^{e}
V_3M_1	18.34^{g}	56.40^{k}	43.60^{a}	10.56^{o}	7.78^{a}
V_3M_2	26.53^{bf}	75.34^{f}	24.66^{f}	20.49^{ij}	6.04^{b}
V_3M_3	26.61^{bf}	77.73^{e}	22.27^{g}	21.11^{i}	5.50^{c}
V_3M_4	24.88^{cg}	74.14^{g}	25.86^{e}	18.89^{k}	5.99^{bc}
V_4M_1	24.77^{cg}	73.33^{g}	26.67^{e}	18.63^{k}	6.14^{b}
V_4M_2	32.97^{ab}	86.50^{a}	13.50^{l}	29.45^{a}	3.52^{g}
V_4M_3	33.33^{a}	86.82^{a}	13.18^{l}	29.86^{a}	3.47^{g}
V_4M_4	31.26^{ac}	84.27^{ab}	15.73^{j}	27.14^{b}	4.12^{ef}
V_5M_1	21.40f^{g}	60.71^{j}	39.29^{b}	13.36^{n}	8.04^{a}
V_5M_2	27.50^{af}	79.25^{d}	20.75^{h}	22.38^{h}	5.12^{cd}
V_5M_3	30.11^{ad}	81.97^{c}	18.03^{i}	24.96^{f}	5.15^{cd}
V_5M_4	26.55^{bf}	77.05^{e}	22.95^{g}	21.03^{i}	5.52^{c}
$LSD_{0.05}$	6.61	1.78	1.34	0.76	0.90
CV (%)	10.62	10.49	8.36	7.31	8.32

Different letters in each column indicate a significant difference ($p<0.5$)

V_1 = Asterix, V_2 = Lady rosetta, V_3 = Courage, V_4 = Diamant, V_5 = BARI TPS-1; M_1 = Control, M_2 = Water Hyacinth, M_3 = Rice straw, M_4 = Rice husk

3.4. Grading parameters of potato

3.4.1. Yield (%) and weight of seed potato

Seed potato percentage showed variability in both varieties and mulch materials. Varieties significantly influenced the yield of seed potato. The highest seed potato (84.05%) was observed in Diamant and the lowest seed potato (70.72%) was in Courage. Rice straw performed better in the case of seed potato yield, especially over control and this trend was almost the same in all five varieties.

Diamant showed its best performance in weight of seed potato (25.52 t ha^{-1}), which was statistically same as Lady rosetta and Courage showed the lowest weight of seed potato (16.84 t ha^{-1}). Additionally, rice straw showed the utmost satisfactory weight of seed potato and it was same with most varieties. No mulch or control treatment gave poor results with existing varieties.

3.4.2. Yield (%) and weight of french-fry potato

French-fry potato was found only in Diamant and Lady rosetta. Diamant produced a higher (0.33%) yield between them. Other varieties did not show any french-fry potato. In mulch materials, other treatments except for water hyacinth and rice straw did not appear with french-fry potato. Moreover, rice straw was seen to perform better with both Diamant and Lady rosetta variety.

The weight of french-fry potato was changeable according to variety and mulch materials. It was seen that the highest weight of french-fry potato (0.10 t ha^{-1}) was observed in Diamant followed by Lady rosetta. Rest three varieties showed no french-fry potato. Rice straw and water hyacinth showed the ability to take a role in french-fry potato production. Between them, rice straw was seen to give a good result with Diamant and Lady rosetta both.

3.4.3. Yield (%) and weight of chips potato

Chips potato was in the highest yield (14.26%) in Courage and the lowest (8.25%) in Diamant. On the other hand, large oval shaped tuber which is selected for chips were found highest in control and the lowest in rice straw. Surprisingly, use of no mulch materials gave higher chips potato with all varieties.

Considering the mulch materials alone, the use of no mulch was seen to perform better than using the mulch materials in the weight of chips potato. Among the five varieties, Courage showed maximum (3.33 t ha^{-1}) weight of chips potato which was statistically like

Table 3. Grading parameters of potato as influenced by different varieties and mulches in ambient condition

Treatment	Seed potato (%)	Weight of seed potato (t ha^{-1})	French-fry potato (%)	Weight of french-fry potato (t ha^{-1})	Chips potato (%)	Weight of chips potato (t ha^{-1})	Non-seed potato (%)	Weight of non-seed potato (t ha^{-1})
				Effect of variety				
Asterix	75.65^{c}	21.32^{b}	NF	NF	11.10^{c}	2.94^{b}	24.35^{b}	6.37^{b}
Lady rosetta	81.37^{b}	24.06^{a}	0.08^{b}	0.03^{b}	9.76^{d}	2.79^{b}	18.63^{c}	5.62^{c}
Courage	70.72^{d}	16.84^{d}	NF	NF	14.26^{a}	3.33^{a}	29.28^{a}	7.25^{a}
Diamant	84.05^{a}	25.52^{a}	0.33^{a}	0.10^{a}	8.25^{e}	2.35^{c}	15.95^{d}	5.06^{d}
BARI TPS-1	76.26^{c}	19.82^{c}	NF	NF	12.72^{b}	3.23^{a}	23.74^{b}	6.58^{b}
$LSD_{0.05}$	1.20	1.51	0.12	0.24	1.01	0.34	1.33	0.26
CV(%)	11.43	10.87	12.79	8.08	12.51	10.77	6.52	9.34
				Effect of mulching				
Control	67.44^{c}	14.80^{c}	NF	NF	15.43^{a}	3.39^{a}	32.56^{a}	7.69^{a}
Water hyacinth	79.66^{b}	23.20^{b}	0.07^{b}	0.02^{b}	10.78^{b}	3.08^{b}	20.34^{b}	6.20^{b}
Rice straw	84.14^{a}	25.24^{a}	0.27^{a}	0.08^{a}	8.18 ^{c}	2.37^{d}	15.86^{c}	5.21^{c}
Rice husk	79.20^{b}	22.82^{b}	NF	NF	10.48 ^{b}	2.86^{c}	20.80^{b}	5.60^{c}
$LSD_{0.05}$	1.15	1.12	0.11	0.04	1.17	0.29	1.27	0.44
CV(%)	11.43	10.87	12.79	8.08	12.51	10.77	6.52	9.34

Different letters in each column indicate a significant difference ($p<0.5$). NF-Not found

Table 4. Grading parameters of potato performed by the combined effect of different varieties and mulches in ambient condition

Treatment	Seed potato (%)	Weight of seed potato (t ha^{-1})	French-fry potato (%)	Weight of french-fry potato (t ha^{-1})	Chips potato (%)	Weight of chips potato (t ha^{-1})	Non-seed potato (%)	Weight of non-seed potato (t ha^{-1})
V_1M_1	67.72^{j}	15.28^{k}	NF	NF	16.59^{b}	3.85^{a}	32.28^{b}	8.16^{a}
V_1M_2	75.19^{f}	21.26^{f}	NF	NF	10.22^{e}	2.90^{f}	24.81^{f}	7.44^{b}
V_1M_3	84.22^{c}	24.99^{d}	NF	NF	7.66^{h}	2.23^{h}	15.78^{k}	5.29^{g}
V_1M_4	75.48^{f}	23.76^{e}	NF	NF	9.92^{f}	2.78^{f}	24.52^{g}	4.59^{h}
V_2M_1	70.04^{i}	16.73^{j}	NF	NF	13.10^{c}	3.17^{d}	29.96^{c}	7.75^{b}
V_2M_2	84.46^{c}	26.34^{c}	NF	NF	8.24^{g}	2.53^{g}	15.54^{k}	4.96^{g}
V_2M_3	86.07^{b}	27.17^{b}	0.33^{b}	0.10^{b}	9.16^{f}	2.87^{f}	13.93^{m}	4.75^{gh}
V_2M_4	84.92^{c}	26.00^{c}	NF	NF	8.54^{g}	2.57^{g}	15.08^{l}	5.03^{g}
V_3M_1	54.44^{k}	9.84^{m}	NF	NF	17.94^{a}	3.28^{d}	45.56^{a}	8.50^{a}
V_3M_2	75.49^{f}	19.40^{h}	NF	NF	12.83^{d}	3.35^{c}	24.51^{g}	7.13^{c}
V_3M_3	78.64^{e}	20.18^{g}	NF	NF	13.92^{c}	3.67^{b}	21.36^{i}	6.43^{de}
V_3M_4	74.31^{fg}	17.95^{i}	NF	NF	12.34^{d}	3.02^{e}	25.69^{e}	6.93^{c}
V_4M_1	73.20^{gh}	17.42^{i}	NF	NF	13.22^{c}	3.22^{d}	26.80^{d}	7.35^{b}
V_4M_2	88.06^{a}	28.83^{b}	0.33^{b}	0.10^{b}	8.86^{g}	2.88^{f}	11.94^{n}	4.14^{i}
V_4M_3	89.96^{a}	29.55^{a}	1.00^{a}	0.30^{a}	3.18^{j}	1.01^{j}	10.04^{o}	3.78^{j}
V_4M_4	84.98^{c}	26.29^{c}	NF	NF	7.75^{h}	2.27^{h}	15.02^{l}	4.97^{g}
V_5M_1	71.80^{i}	14.71^{l}	NF	NF	16.32^{b}	3.45^{c}	28.20^{c}	6.69^{d}
V_5M_2	75.10^{f}	20.17^{g}	NF	NF	13.76^{c}	3.73^{b}	24.90^{f}	7.33^{bc}
V_5M_3	81.83^{d}	24.30^{d}	NF	NF	6.96^{i}	2.06^{i}	18.17^{j}	5.81^{f}
V_5M_4	76.30^{l}	20.08^{g}	NF	NF	13.85^{c}	3.66^{b}	23.69^{h}	6.47^{de}
$LSD_{0.05}$	1.14	0.76	0.07	0.06	0.81	0.18	0.26	0.40
CV (%)	11.43	10.87	12.79	8.08	12.51	10.77	6.52	9.34

Different letters in each column indicate a significant difference ($p<0.5$)

V_1 = Asterix, V_2 = Lady rosetta, V_3 = Courage, V_4 = Diamant, V_5 = BARI TPS-1; M_1 = Control, M_2 = Water Hyacinth, M_3 = Rice straw, M_4 = Rice husk. NF-Not found

BARI TPS-1 and minimum weight of chips potato (2.35 t ha^{-1}) was showed by Diamant. No mulch using showed higher weight in all varieties.

3.4.4. Yield (%) and weight of non-seed potato

Tubers which are undersized or oversized for seed production are considered as non-seed potato. Both the varieties and mulch materials influenced the yield of non-seed potato. In case of variety, Courage gave the highest (29.28%) non-seed potato whereas, the lowest (15.95%) non-seed potato was found from Diamant. Using no mulch showed the highest non-seed potato yield in all varieties.

Taking into account the varieties only, weight of non-seed potato was maximum (7.25 t ha^{-1}) from Courage and minimum non-seed potato (5.06 t ha^{-1}) was from Diamant. Considering mulch materials, using no mulch material was seen to give the highest non-seed potato weight in all five varieties (Table 3,4).

Yield parameters are important factors to know the performance of any crop. In the experiment, we have found that the yield parameters (yield, marketable yield, non-marketable yield) varied with different mulch materials and varieties. Diamant variety showed better performance in total yield, marketable yield percentage and marketable yield weight than other varieties. This trend of result is in agreement with the findings of Mekashaw et al. (2020) and Rahman et al. (2019) where they found better yield in Belete and BARI Alu 40, respectively compared to other varieties. The difference may be caused for the genetical, morphological and environmental factors of the existing varieties (Eaton *et al*., 2017). Tuber size also can vary according to their variety for their peculiar genetical character (Zelelew *et al.*, 2016) that can be influenced by environmental conditions and, principally, by crops management (Pàdua *et al.*, 2012). Non-marketable yield was estimated by measuring the size of tuber. Tuber smaller than 28 mm are mainly considered as non-marketable. Courage was seen to produce more non-marketable yield compared to other varieties. Fetena and Eshetu (2017) explained that non-marketable yield was more dependent on the existing environment with the factors like disease attack, farm practices and harvesting procedure, showing the highest non-marketable yield in Local-1 variety. The result was also similar to the opinion of Kena et al. (2018) where it was seen that interaction effect of variety and year significantly affect non-marketable yield.

Additionally, mulch materials showed differences in yield parameters according to their types. Rice straw showed better performance in our study than other mulches, especially over the no mulch condition, increasing the total tuber and weight of marketable yield along with marketable yield percentage. Lehar et al. (2017) pointed out that straw mulching with close spacing decreases soil temperature and reduces the respiration rate in the root. As a result, the accumulated carbohydrate that acts as reserved nutrients in the potato will increase compared to no mulch condition. Nwosisi et al. (2019) concluded that organic mulch suppresses weed germination in potato by manipulating soil moisture and organic matter and consequently, enhance the yield. Findings of marketable yield conform to the result of Shehata et al. (2019) where it has been explained that mulch treatment minimizes weed plant competition and facilitates larger size tuber production than no mulch condition. Non-marketable yield was the highest in control and lowest in rice straw. El-Wahed et al. (2020) found that mulch materials influence tuber size by increasing the availability of water and nutrient in root zone of the plant, especially in the vegetative stage. Interaction effect of variety and mulch material indicated that, Diamant variety with rice straw could give satisfactory yield attributes over other interactions, particularly from Courage-no mulch treatment condition. Furthermore, water hyacinth and rice husk also gave a better result than control. Water hyacinth while having good water retention capacity and preventing weed growth can increase potassium availability in potato. As a result, the potato was seen to give good yield when used water hyacinth (Alam *et al*., 2017; Ahmed *et al*., 2017). Rice husk having high C/N ratio with soil nitrogen immobilization potentiality and smaller amount of potassium and ash content could favour in the production increasement while protecting soil insect (Juang *et al*., 2021; Meilin and Rubiana, 2018).

Tuber grading is important to evaluate the quality parameters of potato. It is done based on tuber size or tuber weight. Tuber that are in range of 28-55 mm in size and not less than 20 gm in weight are considered as seed potato. Diamant performed better in producing seed potato both in aspect of yield percentage and weight, in our experiment. Seed potato production can be affected by variety and this is also proved by Sikder et al. (2017) where it is seen that different genotypes with varied nutrient conditions show changes in seed potato production. Whereas, Komen et al. (2018) explained the changes as the result of different genotypes and their existing location, which facilitates tuber with the early emergence, fast growth with fast yield. French-fry potato and chips potato was higher in Diamant and Courage, respectively. This result also conforms to the findings of Aswani and Kusmana (2020) who explained that the shape and weight of tuber suitable for chips or french-fry potato is the contribution of genetic character mainly. Cultivars can produce uniform size tuber according to their genetic variation with the existing environmental and cultivation conditions (Araújo *et al*., 2016). The highest non-seed potato was observed in Courage. This variety is seen to produce more oversized tuber that can be the reason for non-seed tuber production. Large or small size tuber production is the contribution of the inherent quality of the used cultivars (Getie *et al*., 2018). Mallick et al. (2017) concluded that, oversized tuber production is changeable according to the genotypical variation and these tuber are not economically feasible for a breeder for seed production. Mulch material influences seed potato production by altering the tuber size. Rice straw show the highest seed tuber production in our experiment. Straw mulches help in early vegetative growth and that can improve tuber production as well. Bharati et al. (2020) also experienced a similar trend of result and explained that mulch prioritizes quality size tuber production by improving water and nutrient uptake which increases individual tuber growth of potato. French-fry potato was higher with rice straw but no mulch gave the highest chips potato. Tuber >75 mm are considered as french-fry and this type of jumbo tuber was found by Zhang et al. (2020) where film mulch helps in maintaining high temperature in the tuber growth stage that ultimately produced jumbo tuber in size and weight both. Chips potato yield was also seen to increase in case of no mulch or soil mulch by Pulok et al. (2016) but this is different from the findings of Ahmed et al. (2017) where maximum (>55 mm) tuber produced under water hyacinth treatment which is considered as chips potato. Mulch materials can perform differently according to the existing environmental condition and given variety. On the other hand, maximum non-seed tuber was seen in no mulch treatment. As mulch materials serve a better physiological state for the crop, it is predictable to see lower size tuber formation in no mulch comparing mulch practices. Kiptoo et al. (2018) suggested that use of mulch materials is preferable to produce standard size tuber rather than no mulch as it can modify the temperature and moisture condition of the soil. Therefore, rice straw showed a better outcome in most of the parameters of our experiment. It may be happened due to the good source of N, K and silicate content of rice straw that is very important for shallow rooted potato (Salamba *et al.,* 2021). Moreover, rice straw has low thermal activity, higher retention capacity, good drainage and aeration ability which in turn give better root growth and higher crop yield (Lehar *et al*., 2017; El-Wahed *et al*., 2020).

4. Conclusion

Potato sensitivity to the presence of moisture is common particularly in the case of yield and quality. Using mulch materials is a potential way of conserving soil moisture and in addition to maintain the tuber quality of potato. In our experiment, Diamant gave higher tuber yield, marketable yield, seed potato yield and french-fry potato, in contrast to Courage, which gave more chips potato than others. Among the three types of mulch materials used, rice straw performed best with the highest results in total yield, marketable yield, seed tuber and french-fry tuber production. However, as expected, using no mulch materials showed the lowest results in almost all cases, except chips tuber production. Other mulch materials, which are easily available or budget-friendly can be used to compare the performance with rice straw. Inorganic mulch also can be used to see the effect on potato. Moreover, currently released high yielding potato varieties can be considered for further research.

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Competing interests

Authors have declared that no competing interests exist.

Authors’ contributions

TSR helped in designing the study, performing the statistical analysis and writing the protocol. The first draft of the manuscript was written by FN. MTH, JF and FN handled the analysis part. RN, FN and GCM conducted in literature searching. The final manuscript was read and approved by all others.

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