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PHOSPHORUS DOSE AND POTASSIUM SOURCE ON YIELD AND EXPORT QUALITY OF POTATO

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Abstract

In Bangladesh, potato (*Solanum tuberosum* L.) lacks optimum quality for export or processing industries. Optimum utilization of specific plant nutrients can improve quality. The experiment was conducted to evaluate the best dose(s) of phosphorus in combination with potassium sources as they affect potato tuber quality. The experiment consisted the factors: phosphorus dose(4); P_1 = 200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P; P_2 = 220 kg ha^{-1} TSP @ 46.81 kg ha^{-1} P, P_3 = 240 kg ha^{-1} TSP @ 51.06 kg ha^{-1} P and P_4 = 260 kg ha^{-1} TSP @ 55.32 kg ha^{-1} P, and potassium sources (3); K_1= KCl (250 kg ha^{-1} KCl @130 kg ha^{-1} K), K_2 = KH_2PO_4 (452.19 kg ha^{-1} KH_2PO_4 @130 kg ha^{-1} K) and K_3 = K_2SO_4 (288.6 kg ha^{-1} K_2SO_4 @130 kg ha^{-1} K). The interaction of phosphorus doses and potassium sources affected most parameters studied. The highest yield (35.35 t ha^{-1}), caned (10.35 t ha^{-1}), chips (28.06 t ha^{-1}), and French fry (0.367 t ha^{-1}) were from P_3K_2, P_4K_2, P_3K_2, P_3K_1 respectively; the lowest yield (30.90 t ha^{-1}), caned (5.59 t ha^{-1}) and chips (20.01 t ha^{-1}) were from P_1K_3, P_4K_1, P_1K_3 respectively. The highest dry matter (22.85%), starch (17.936%), antioxidant (630.12 Trolox µMol/100 g FW), and polyphenol (92.994 GA mg/100 g FW) were from P_1K_3; the lowest reducing sugar (0.1713 mg g^{-1} FW) and non-reducing sugar (0.3290 mg g^{-1} FW) were from P_1K_3. It appeared that 200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P as a dose of phosphorus and K_2SO_4 as sources of potassium may be a suitable combination to produce export and processing quality potato.

Keywords: Chips, Dry matter, French fries, Potato, Processing quality, Specific gravity.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is rich in carbohydrates, minerals and contains a large amount of high-quality proteins, vitamin C, and minerals (Brown, 2005). Potato is a short-cycle crop and has high production capacity compared to other crops; it is highly influenced by the application of various nutrients to the soil (Luz et al., 2013). Research had conducted to study the effects of type, rates, and forms of fertilizers on potato tuber yields and quality (Zorb et al., 2014). High rates of phosphate fertilizers are applied in its cultivation for larger tubers and higher tuber yield (Luz et al., 2013). Phosphorus affects tuber size and dry matter percent (indicated by specific gravity) (Dyson and Watson, 1971; Freeman et al., 1998; Rosen et al., 2014). Physical and chemical characteristics, and nutritional composition of potato tubers, may vary depending on cultivar, plant maturity, availability of nutrients in the soil, fertilization process, and climate (Rosen et al., 2014). Phosphorus fertilization increases concentrations of ascorbic acid, nitrogen, and protein in tubers (Klein et al., 1980). To increase the specific gravity of tubers, phosphorus fertilization can change the texture, color, and flavor of cooked tubers (Sheard and Johnston, 1958). There is little information on the effect of phosphorus on the nutritional composition of potato tubers (Rosen et al., 2014).

Potassium influences the quantity and quality of potatoes (Lakshmi et al., 2012) through enzyme activation, stomatal conductance, photosynthesis, protein synthesis, and transport of sugars and starch (Werij et al., 2007). Potassium chloride (KCl), potassium sulfate (K_2SO_4), monopotassium phosphate (KH_2PO_4), potassium nitrate (KNO_3), and potassium silicate ($K_2O{\cdot}4SiO_2$) are used as plant fertilizers (Magen, 2004). Potassium silicate ($K_2O{\cdot}4SiO_2$) improved the growth and yield of plants (Ali et al., 2021). The quality and chemical composition of potato tubers are influenced by genetics, soil fertility, applied nutrients, and weather (Rytel et al., 2013). Potassium affects dry matter percent, increases ascorbic acid content, decreases reducing sugars, phenol contents, and enzymatic degradation (Werij et al., 2007). Potato quality improvement is key for exporting potatoes to overseas markets (Pandey et al., 2000). The study was conducted to examine the effects of different phosphorus doses and potassium sources on the quality of potatoes.

MATERIALS AND METHODS

The experiment was conducted from November 2019 to February 2020 at the Agronomy research field of Sher-e-Bangla Agricultural University (SAU), Bangladesh. The experimental field belongs to the Agroecological zone (AEZ) of the Modhupur Tract, AEZ-28. The experimental area was located in the subtropical monsoon climatic zone, with winter from November to February. Extensive sunshine and moderately low temperature prevail during this period, which is suitable for potato growing in Bangladesh (Anonymous, 2020). The site has available irrigation and drainage facilities and is situated above flood level. The soil was composed of 26% sand, 43% silt, and 31% clay, having a sandy loam texture with organic matter at 1.15%. The experiment consisted dose of four phosphorus doses (P_1 = 200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P, P_2 = 220 kg ha^{-1} TSP @ 46.81 kg ha^{-1} P, P_3 = 240 kg ha^{-1} TSP @ 51.06 kg ha^{-1} P and P_4 = 260 kg ha^{-1} TSP @ 55.32 kg ha^{-1} P), and three potassium sources (K_1 = KCl (250 kg ha^{-1} KCl @ 130 kg ha^{-1} K), K_2= KH_2PO_4 (452.19 kg ha^{-1} KH_2PO_4 @130 kg ha^{-1} K) and K_3 = K_2SO_4 (288.6 kg ha^{-1} K_2SO_4 @ 130 kg ha^{-1} K). The experiment was arranged in a two-factorial split-plot design with three replications. The total area was 300 m^2, with a length of 24 m and a width of 11.33 m. The phosphorus treatments were assigned in the main plot, and sources of potassium were in the subplot. There were 36 plots, each 2.6 m × 1.2 m. The distance between blocks and plots was 1.5 m and 0.8 m, respectively. Potato seed BARI alu-29 (‘Courage’) was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Manure and fertilizer were applied to the experimental plots at the recommended rates (Anonymous, 2017).

Haulm cutting was done at 85 DAP (days after planting) when 60-70% of plants showed senescence and tops started drying. After haulm cutting, tubers were kept in the soil for seven days for skin hardening and then harvested by hand. Potatoes from each plot were separately harvested, bagged, tagged, and brought to the laboratory. Data was taken on processing quality: dry matter content, specific gravity, total soluble solid, starch, reducing sugar, non-reducing sugar, antioxidant, and polyphenol content. The data were statistically analyzed using analysis of variance with Statistix (ver. 10, Analytical Software, Tallahassee, FL), and the means were separated by the least significant difference (Gomez and Gomez, 1984). Correlations were calculated on the basis of combined effect data from different parameters.

RESULTS AND DISCUSSION

Significant variation was found in the case of the yield of potato due to the combined effect of different doses of phosphorus and sources of potassium. The maximum yield of potato was found from P_3K_2 and P_4K_2 treatment combination; and the minimum was recorded from P_1K_1 (Table 1). In the aspect of canned, 25-35 mm, different combination of phosphorus dose and different sources of potassium was found statistically significant. For Canned potato, the highest was observed from P_4K_2, whereas the lowest was recorded from P_4K_1, P_4K_3, P_4K_1, P_3K_3, P_3K_2, P_2K_2, and P_1K_1 (Table 1).

Table 1. Interaction[a] effects of phosphorus and source of potassium on yield and category of tubers based on uses in potato tubers

Treatments	Yield	Category of tubers based on uses		
		Caned (25-45 mm)	Chips (45-75 mm)	French Fry (>75 mm)
Phosphorus dose				
P_1	30.30 c	7.35 a	22.94 c	0.00 d
P_2	31.12 b	6.50 b	24.43 b	0.167 b
P_3	32.88 a	6.15 c	26.39 a	0.341 a
P_4	30.47 c	7.22 a	23.14 bc	0.099 c
LSD (0.05)	0.425	0.315	1.380	0.012
Level of significance	**	**	**	**
CV (%)	2.18	4.01	4.94	7.09
Potassium source				
K_1	31.39 b	6.26 c	24.98 a	0.152
K_2	32.43 a	7.38 a	24.90 a	0.153
K_3	29.75 c	6.79 b	22.81 b	0.151
LSD (0.05)	0.181	0.476	1.908	-
Level of significance	**	**	*	NS
CV (%)	3.67	8.08	9.10	-
Interaction				
P_1K_1	31.76 f	6.22c-f	24.19 bc	0.000 d
P_1K_2	33.03 de	6.93 c	24.63 bc	0.000 d
P_1K_3	30.90 g	8.91 b	20.01 d	0.000 d
P_2K_1	32.67 e	6.66cd	24.66abc	0.240 c
P_2K_2	34.00 bc	6.42c-f	25.68ab	0.260 c
P_2K_3	32.69 e	6.44cde	22.97bcd	0.000 d
P_3K_1	34.07 b	6.56cde	26.17ab	0.367 a
P_3K_2	35.35 a	5.80ef	28.06 a	0.350 a
P_3K_3	33.45 cd	6.08def	24.94ab	0.307 b
P_4K_1	33.04 de	5.59 f	24.90abc	0.000 d
P_4K_2	34.82 a	10.35 a	21.23cd	0.000 d
P_4K_3	32.61 e	5.73ef	23.31bcd	0.297 b

Treatments	Yield	Category of tubers based on uses		
		Caned (25-45 mm)	Chips (45-75 mm)	French Fry (>75 mm)
LSD (0.05)	0.662	0.838	3.403	0.031
Significance level	*	**	*	**
CV (%)	4.07	8.08	9.10	13.28

[a] data in the interaction analyzed with Least Squares Means and means separated with Least Significant Differences.

[b] P_1 = 200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P, P_2 = 220 kg ha^{-1} TSP @ 46.81 kg ha^{-1} P, P_3 = 240 kg ha^{-1} TSP @ 51.06 kg ha^{-1} P, and P_4 = 260 kg ha^{-1} TSP @ 55.32 kg ha^{-1} P; K_1 = KCl (250 kg ha^{-1} KCl @130 kg ha^{-1} K), K_2 = KH_2PO_4 (452.19 kg ha^{-1} KH_2PO_4 @130 kg ha^{-1} K), and K_3 = K_2SO_4 (288.6 kg ha^{-1} K_2SO_4 @130 kg ha^{-1} K).

[c] Values in a column followed by the same letter are not statistically different, $p<0.05$.

In an aspect of Chips, 45-75 mm, different combination of Phosphorus dose and different sources of potassium was found statistically significant. For Chips potato, the highest was observed from P_3K_2, P_2K_1, P_2K_2, P_3K_1, P_3K_3, and P_4K_1 treatment combination, whereas the lowest was recorded from P_1K_3, P_2K_3, P_4K_2, and P_4K_3 (Table 1). In the aspect of French fry, >75 mm, different combination of phosphorus doses and different sources of Potassium was found statistically significant. For French fry potato, the highest was observed from P_3K_1, P_3K_2 whereas the lowest was recorded from P_1K_1, P_1K_2, P_1K_3, P_2K_3, P_4K_1, and P_4K_2 (Table 1).

Dry matter content was affected by phosphorus dose, not by potassium source, but the interaction was significant. The highest dry matter content in potato tubers was from P_1K_3, P_1K_1, P_1K_2, P_1K_2, P_2K_1, P_2K_2, P_2K_3, P_3K_1, and P_3K_3 treatment combination, and the lowest was recorded from P_4K_3 (Table 2).

Table 2. Interaction[a] effects of phosphorus and source of potassium on dry matter contents, total soluble solid (TSS) and starch in potato tubers

Treatments	Dry matter content (%)	Specific gravity (g/cc)	Total soluble solids TSS (ºBrix)	Starch (%)
Phosphorus dose				
P_1	22.19 a	1.0798	3.97 d	17.075 a
P_2	21.59 ab	1.0679	4.27 c	15.024 b
P_3	21.19 b	1.0655	4.70 b	15.579 b
P_4	18.72 c	1.0556	4.93 a	12.579 c
LSD (0.05)	0.962	-	0.122	0.8660

Treatments	Dry matter content (%)	Specific gravity (g/cc)	Total soluble solids TSS (ºBrix)	Starch (%)
Level of significance	**	NS	**	**
CV (%)	3.98	2.74	2.36	4.98
Potassium source				
K_1	21.00	1.0688	4.45 b	14.875 b
K_2	20.67	1.0519	4.65 a	14.333 b
K_3	21.10	1.0808	4.30 b	15.985 a
LSD (0.05)	-	-	0.175	1.0175
Level of significance	NS	NS	**	*
CV (%)	-	-	3.44	7.80
Interaction				
P_1K_1[b]	22.15ab	1.0829	3.90 e	16.834 a
P_1K_2	21.58abc	1.0566	4.10 de	16.455 a
P_1K_3	22.85 a	1.0998	3.90 e	17.936 a
P_2K_1	21.55abc	1.0693	4.30cd	14.432bcd
P_2K_2	20.98a-d	1.0525	4.60 bc	14.473bcd
P_2K_3	22.25ab	1.0819	3.90 e	16.167ab
P_3K_1	21.15a-d	1.0654	4.70 b	16.098abc
P_3K_2	20.58bcd	1.0513	4.80ab	14.167cd
P_3K_3	21.85ab	1.0797	4.60 bc	16.473 a
P_4K_1	19.15 de	1.0578	4.90ab	12.136 e
P_4K_2	19.55cde	1.0474	5.10 a	12.238 e
P_4K_3	17.45 e	1.0617	4.80ab	13.363 de
LSD (0.05)	2.196	-	0.310	1.8707
Level of significance	*	NS	*	*
CV (%)	6.69	-	4.52	7.80

[a] data in the interaction analyzed with Least Squares Means and means separated with Least Significant Differences.

[b]P_1 =200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P, P_2 =220 kg ha^{-1} TSP @ 46.81 kg ha^{-1} P, P_3 =240 kg ha^{-1} TSP @ 51.06 kg ha^{-1} P,and P_4 =260 kg ha^{-1} TSP @ 55.32 kg ha^{-1} P; K_1 = KCl (250 kg ha^{-1} KCl @130 kgha^{-1} K), K_2 = KH_2PO_4 (452.19 kg ha^{-1} KH_2PO_4 @130 kg ha^{-1} K), and K_3 = K_2SO_4 (288.6 kg ha^{-1} K_2SO_4 @130 kg ha^{-1} K).

[c] Values in a column followed by the same letter are not statistically different, $p<0.05$.

Phosphorus dose and potassium source, and the interaction, were not significant for specific gravity. The average specific gravity of the potato was found 1.067 gcm^{-3}. Phosphorus dose, potassium source, and the interaction affected total soluble solids (Table 2). The highest TSS in potato tubers was from P_4K_2, P_3K_2, P_4K_1, and P_4K_3 combinations, and the lowest was recorded from P_1K_1, P_1K_2, P_1K_3 and P_2K_3 (Table 2). Phosphorus dose, potassium source, and the interaction affected starch content. The highest starch content in potato tubers was from P_1K_3, P_1K_1, P_1K_2, P_2K_3, P_3K_1, and P_3K_3; the lowest was from P_4K_1, P_4K_2, and P_4K_3 (Table 2).

Phosphorus dose, potassium source, and the interaction affected reducing sugar content. The highest reducing sugar content in potato tubers was recorded from P_4K_1 and P_4K_2; the lowest was from P_1K_3, P_3K_1, P_1K_1, P_1K_2, and P_2K_3 (Table 3). Phosphorus dose, potassium source, and the interaction affected reducing sugar content. The highest non-reducing sugar content in potato tubers was from $P_4K_1$and P_4K_2; the lowest was from P_1K_3, P_1K_1, P_1K_2, and P_2K_3 (Table 3). Phosphorus dose, potassium source, and the interaction affected antioxidants. The highest antioxidant content in potato tubers was recorded from P_1K_3, P_1K_2, and P_3K_1; the lowest was from P_4K_1, P_2K_1, P_2K_2, P_4K_2, and P_4K_3 (Table 3). Phosphorus dose, potassium source, and the interaction affected polyphenols. The highest polyphenol content in potato tubers was from P_1K_3, P_1K_1, P_2K_1, P_2K_3, P_3K_1, and P_3K_3; the lowest was from P_4K_2, P_2K_2, P_3K_2, and P_4K_1 (Table 3).

Table 3. Interaction[a] effects of phosphorus and source of potassium on reducing sugar, non-reducing sugar, antioxidant and polyphenol in potato tubers

Treatments	Reducing sugar (mg g^{-1} FW)	Non-reducing sugar (mg g^{-1} FW)	Antioxidant (Trolox µMol $100g^{-1}$ FW)	Polyphenol (GA mg $100g^{-1}$ FW)
Phosphorus dose				
P_1	0.1745 c	0.3333 d	601.17 a	84.137 a
P_2	0.1885 b	0.3534 c	522.17 c	79.468 ab
P_3	0.1875 b	0.3814 b	569.21 b	76.800 b
P_4	0.3482 a	0.5348 a	497.06 d	68.135 c
LSD (0.05)	0.0050	0.0126	17.736	6.6142
Level of significance	**	**	**	*
CV (%)	1.96	2.74	2.81	7.43
Potassium source				
K_1	0.2267 a	0.4176 a	541.42 b	79.271 a
K_2	0.2307 a	0.3990 b	532.92 b	66.891 b
K_3	0.2166 b	0.3855 b	567.87 a	85.243 a
LSD (0.05)	0.0071	0.0163	21.798	6.5815

Treatments	Reducing sugar (mg g^{-1} FW)	Non-reducing sugar (mg g^{-1} FW)	Antioxidant (Trolox µMol $100g^{-1}$ FW)	Polyphenol (GA mg $100g^{-1}$ FW)
Level of significance	**	**	*	**
CV (%)	3.66	4.70	4.60	9.86
Interaction				
P_1K_1[b]	0.1788 ef	0.3399 efg	582.25 b	85.774 abc
P_1K_2	0.1735 ef	0.3310f g	591.14 ab	73.642 cde
P_1K_3	0.1713 f	0.3290 g	630.12 a	92.994 a
P_2K_1	0.1998 c	0.3655 de	512.25 cde	80.771a-d
P_2K_2	0.1933 cd	0.3590 def	513.14 cde	69.639 def
P_2K_3	0.1723 ef	0.3358 efg	541.12 c	87.995 ab
P_3K_1	0.1725 ef	0.4041 c	592.25 ab	80.767 a-d
P_3K_2	0.2055 c	0.3749cd	526.25 cd	65.640 ef
P_3K_3	0.1845 de	0.3651 de	589.12 b	83.992 abc
P_4K_1	0.3558 a	0.5610 a	478.92 e	69.772 def
P_4K_2	0.3505 ab	0.5312 ab	501.14 de	58.641 f
P_4K_3	0.3383 b	0.5121 b	511.12 cde	75.993 b-e
LSD (0.05)	0.0127	0.0294	39.711	12.596
Level of significance	**	*	*	*
CV (%)	3.66	4.70	4.60	9.86

[a] data in the interaction analyzed with Least Squares Means and means separated with Least Significant Differences.

[b] P_1 = 200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P, P_2 = 220 kg ha^{-1} TSP @ 46.81 kg ha^{-1} P, P_3 = 240 kg ha^{-1} TSP @ 51.06 kg ha^{-1} P, and P_4 = 260 kg ha^{-1} TSP @ 55.32 kg ha^{-1} P; K_1 = KCl (250 kg ha^{-1} KCl @130 kg ha^{-1} K), K_2 = KH_2PO_4 (452.19 kg ha^{-1} KH_2PO_4 @130 kg ha^{-1} K), and K_3 = K_2SO_4 (288.6 kg ha^{-1} K_2SO_4 @130 kg ha^{-1} K).

[c] Values in a column followed by the same letter are not statistically different, $p<0.05$.

Phosphorus is an important nutrient to increase potato yield (Rozo and Nustez, 2011). Potato yield was increased with the increase of Phosphorus dose up to P_3 and thereafter decreased. Among the potassium sources, K_2 gave the maximum potato yield because it provided extra phosphorus nutrients in the soil. Dry matter content is an important factor for processing quality. Different processed potato products require different dry matter content. For canned (<18%), French fry (>20%), dehydrated (>20%), and chips (>20%), specific gravity are required. Higher dry matter content is required for good quality chip and French fry items because higher dry matter reduces oil absorption and increases the crispy texture of the product (Marwaha et al., 2010). Ozturk et al. (2010) reported dry matter of potatoes decreased with the increase in phosphorus dose. Sharma and Sud (2001) reported potassium source does not have a significant effect on the dry matter content of the potato. Specific gravity is an important factor for processing quality (Gunadi, 2009). Different processed potato products require different specific gravity. For canned (<1.07 g cm^{-3}), french fried (1.08 g cm^{-3}), dehydrated (1.08 g cm^{-3}), chips (>1.08 g cm^{-3}), specific gravity is required (Marwaha et al., 2010). Specific gravity of the potato did not respond to the interaction of phosphorus dose and potassium source, which was also reported by Rozo and Nustez (2011). Ozturk et al. (2010) reported starch content of potato tuber decreased with the increase of phosphorus. Reducing sugar is an essential factor for processing quality, especially for fried products. Higher reducing sugar increases dark color and bitter taste during frying. For good quality fry items, low reducing sugar (<0.1%) based on a fresh weight basis is recommended (Marwaha et al., 2010). Non-reducing sugar increased with the increase in phosphorus level (Rozo and Ñústez, 2011). Antioxidants and polyphenols were decreased with the increase in phosphorus level (Rozo and Nustez, 2011).

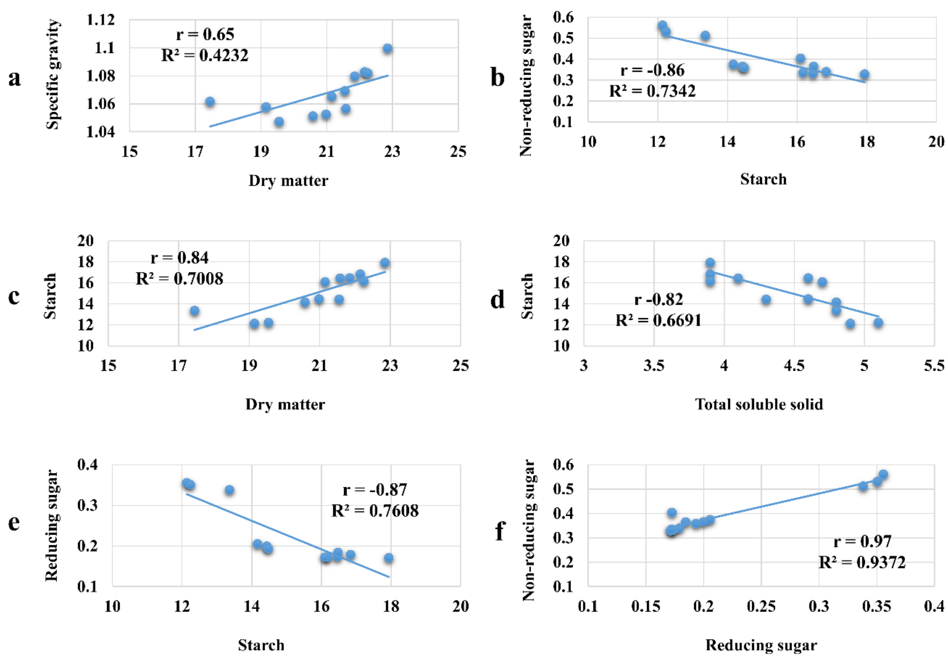

Figure 1. Linear relationships between a) specific gravity and dry matter content of potato tuber, b) non-reducing sugar content and starch of potato tuber, c) starch and dry matter content of potato tuber, d) starch and total soluble solid of potato tuber, e) reducing sugar content and starch of potato tuber and f) non-reducing sugar content and reducing sugar content of potato tuber.

A strong positive linear relationship occurred between specific gravity and dry matter content of potato tuber (Fig. 1a), as previously reported by Ferdous et al. (2020). A strong negative linear relationship occurred between non-reducing sugar content and starch content of potato tuber (Fig. 1b), as previously reported by Braun et al. (2016). Starch is an important component of dry matter content. A strong positive linear relationship occurred between starch and dry matter content of potato tuber (Fig. 1c), as previously reported by Abebe et al. (2012). A strong negative linear relationship occurred between starch and the total soluble solid of potato tuber (Fig. 1d), as previously reported by Abbas et al. (2011). A strong positive linear relationship occurred between reducing sugar content and starch of potato tuber (Fig. 1e), as previously reported by Mostofa et al. (2019). A strong positive linear relationship occurred between the non-reducing and reducing sugar content of potato tuber (Fig. 1f), as previously reported by Braun et al. (2016) and Ferdous et al. (2019).

CONCLUSION

In this research, we found different combinations (P_3K_2 and P_4K_2) of phosphorus dose and potassium source gave maximum potato yield. But in consideration of potato quality, 200 kg ha^{-1} TSP @ 42.55 kg ha^{-1} P and 288.6 kg ha^{-1} K_2SO_4 @ 130 kg ha^{-1} K gave the best processing quality potato, which can be used to produce potato that meets export requirements.

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