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Original Research Article

Bio chemical Quality of Tubers as Influenced by Planting Time, Spacing and Nutrition Levels in Potato cv. Kufri Surya

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A B S T R A C T

The field experiment was carried out during *rabi* season of 2018-19 and 2019-20 at College farm, College of Horticulture, VR Gudem, West Godavari Distract of AP. There were 18 treatments consisting of 3 factors *viz.*, 3 planting dates (D_1:Oct-15th, D_2:Nov-1st and D_3:Nov-16th), 2 plant spacings (S_1:60x20 cm, S_2:75x20 cm) with 3 NPK doses (F_1:120:60:150, F_2:160:80:200 and F_3: 200:100:250 kg ha^{-1}). Treatments were laid in Factorial RBD with replicated thrice. The objective is to study the effect of planting time, spacing and NPK levels on quality potato. As per pooled results, quality characters *viz.*, TSS, protein, ascorbic acid, starch, tuber dry matter, specific gravity, reducing, total and non-reducing sugars were recorded in November 1st planting (D_2). Among the spacings, wider spacing of 75x20 cm (S_2) was recorded the superior values for most of the tuber quality parameters while spacing showed non-significant effect on TSS. NPK level F_2 (160N:80P:200K kg ha^{-1}) recorded the highest values for all the quality parameters except protein content whereas NPK level F_3 (200N:100P:250K kg ha^{-1}) noticed the maximum protein content. All the two way treatment interactions were found to be non-significant whereas in case of three way interactions were found to be significant for the most of the quality parameters. $D_2S_2F_2$ combination proved as a best in most of the quality parameters.

Keywords

TSS, Protein, starch, Dry matter planting time, spacing, NPK levels, Quality and sugars

Introduction

Potato (*Solanum tuberosum* L.) also known as white or Irish potato, is the fourth most important staple food crop in the world after rice, wheat and maize. This crop can be consumed as a vegetable and also as the major food item. Its yield and quality are both dependent on variety and cultural practice as well as environmental conditions, including temperature, light and rainfall (Dallacosta *et al.*, 1997). In India, potato is cultivated in an area of 2.15 lakh ha with an annual production of 485.29 lakh tones and productivity of 20.55 t ha^{-1} (FAO, 2018). Potato is an important crop for the densely populated areas of Asia because it produces more dry matter, well balanced protein and more calories per unit area of land and per unit time than any other major food crops (Chadha and Grewal, 1993). A potato tuber contains 80 % water and 20% dry matter consisting of carbohydrates (22.6g), which are essential for energy (97 kcal), 14% starch, 2% protein, 2% sugars, 1% minerals like

potassium, phosphorous, magnesium, iron, 0.6% fibre, 0.1% fat and vitamins like thiamin, riboflavin, niacin, pyridoxine and ascorbic acid per 100 g fresh weight (Gopalan *et al*., 1972).

Potato planting time for each region is one of the factors that have a significant role in the performance of this product. Each stage of growth coincide with environmental conditions is desired. Delayed planting dates cause yield and quality reduction (Ahmed *et al.*, 2017). The optimization of plant density is one of the most important subjects of potato production management, because it affect seed cost, plant development, yield and quality of the crop (Bussan *et al.*, 2007). Nitrogen is essential for better plant growth and more dry matter production (Roy and Jaiswal, 1998), whereas phosphorus fertilization contributes to early development, tuberization and enhances tuber maturation. Potassium influences both yield and tuber quality and also enhances plant resistance. The quality parameters like dry matter, specific gravity, starch contents, vitamin-C and protein contents were also affected with P and K fertilization (Muhammad *et al.*, 2015). Low NPK fertilization leads to reduction in growth, yield and quality in potato and also plants show nutrient deficiency symptoms. The present experiment was carried out with potato variety Kufri Surya (heat tolerant variety) to investigate the effect of different plating times, spacings and NPK nutrition on yield and quality of potato under costal region of Andhra Pradesh.

Materials and Methods

A field experiment was conducted at College of Horticulture, Venkataramannagudem, Dr. YSRHU, West Godavari District of Andhra Pradesh during winter seasons of 2018-19 and 2019-20 on "Bio chemical quality of tubers as influenced by planting time, spacing and nutrition levels in potato Cv. Kufri Surya". There were 18 treatment combinations consisting of three factors *viz.*, planting times (dates) (3 levels *viz*., D_1: October 15th, D_2: November 1st and November 16th), plant spacings (2 levels *viz*., S_1: 60 cm x 20 cm, S_2: 75 cm x 20 cm) with F_1: 120:60:150 kg ha^{-1}, F_2: 160:80:200 kg ha^{-1} and F_3: 200:100:250 kg ha^{-1}). The treatments were laid in a factorial randomized block design (FRBD) replicated thrice under open field conditions with Kufri Surya variety. FYM @ 25-30 t ha^{-1} was applied in the last ploughing. NPK fertilizers were applied in the form of urea, single super phosphate and muriate of potash as per the treatments. Full dose of SSP, 1/3rd dose of urea and MOP were applied in the last ploughing as basal dose. The remaining dose of Urea and MOP were applied in two equal split doses, first dose at 30 DAP and final dose at 50 DAP. Following observations were recorded during first year, second year and their pooled analysis and the pooled data presented in tables *viz.*, TSS, protein content, ascorbic acid content, starch content, tuber dry matter, tuber specific gravity and sugars contents (reducing, total and non-reducing).

Weather during crop period

The mean maximum day temperatures during experimentation ranged from 28.29 to 35.86 ^{o}C during first year and 28.86 to 34.86 ^{o}C during second year. The mean minimum temperatures were recorded as 18.0 - 23.71 ^{o}C (2018-19) and 19.57 to 23.29 ^{o}C (2019-20). The mean weekly morning and evening relative humidity during first year recorded as 95.86% and 35.71% respectively while, in second year the same were recorded as 94.86% in morning and 36.0% in evening. A total rainfall of 83.10 mm in 2018-19 and 109.70 mm in 2019-20 (42nd - 09th standard week) were received during the crop growth

period and the meteorological data of both the years are presented in Table 4.

Results and Discussions

Total Soluble Solids (^oB)

The highest total soluble solids (TSS) were observed in tubers harvested from 1st November planting whereas the lowest TSS was recorded in the tubers planted on 15th October (Table 1). The total soluble solids were maximum in F_2 (NPK @ 160:80:200 kg ha^{-1}) and minimum in F_1 (NPK @ 120:60:150 kg ha^{-1}). The plant spacing and interaction effect were non-significant in all two way and three way treatment combinations of planting time (D) x spacing (S) x NPK level (F).

Protein content (mg 100 g^{-1})

The pooled results exhibited the superiority of November 1st planting in respect of protein content being maximum and the same was minimum under October 15th planting (Table 1). Among spacings, the plants at 75 x 20 cm spacing produced tubers having significantly higher protein content followed by those spaced at 60 x 20 cm dimensions. Increase in NPK level also increased protein content. The highest and the lowest protein contents were recorded when NPK was applied @ 200:100:250 kg ha^{-1} (F_3) and NPK @ 120:60:150 kg ha^{-1} (F_3), respectively. All the two way treatment interactions was found to be non-significant whereas in three way interactions, the combination of November 1st planting spaced at 75 x 20 cm with NPK level @ 200:100:250 kg ha^{-1} ($D_2S_2F_3$) showed the highest protein content and the least protein content was observed with a treatment combination of October 15th planting + spacing of 60 x 20 cm + NPK@ 120:60:150 kg ha^{-1} ($D_1S_1F_1$).

Ascorbic acid content (mg 100 g^{-1})

The plants set out on November 1st recorded the maximum ascorbic acid content but it was at par with November 16th planting (Table 1). While, October 15th planting recorded the minimum ascorbic acid content. Among plant spacings, the plants at 75 x 20 cm (S_2) and 60 x 20 cm (S_1) spacings produced higher and lower ascorbic acid contents, respectively but both were statistically at par with each other. Ascorbic acid content differed significantly due to NPK levels and it was at the highest with NPK applied @ 160:80:200 kg ha^{-1} and the same was statistically at par with NPK @ 200:100:250 kg ha^{-1}. It was lowest with the application of NPK @ 120:60:150 kg ha^{-1}. Regarding to interactions, all the two way treatment interactions was found to be non-significant whereas in three way interactions, $D_2S_2F_2$ combination (November 1st planting + 75 x 20 cm spacing + NPK @160:80:200 kg ha^{-1}) registered the highest ascorbic acid content which was at par with treatments combinations of $D_2S_1F_2$ and $D_3S_2F_2$. The lowest ascorbic acid content was noticed under D_1 S_2 F_1 combination (October 16th planting + 75 x 20 cm spacing + NPK @120:60:150 kg ha^{1}) and it was at par with treatments of D_1 S_1 F_1, D_1 S_2 F_2, D_1 S_1 F_3, D_3 S_1 F_1 and D_2 S_1 F_1.

Starch content (%)

From different planting times, starch content with November 1st planting was at the highest whereas October 16th planting exhibited the lowest starch content (Table 2). Similarly, the superior starch content was observed at a wider spacing of 75 x 20 cm followed by closer spacing of 60 x 20 cm. Among NPK levels, maximum starch content was registered from the plants supplied with NPK @ 160:80:200 kg ha^{-1} and it was minimum with NPK applied @ 120:60:150 kg ha^{-1}. With regard to interactions, all the two way treatment interactions was found to be non-significant whereas in three way interactions, the highest starch content was recorded from the treatment combination of $D_2S_2F_2$

followed by $D_3S_2F_3$ and the lowest starch content was noticed in $D_1S_1F_1$ combination.

Tuber dry matter (%)

The effect of planting times, spacing, NPK levels and their interaction on tuber dry matter (Table 2) was found significant while the interaction effect was non-significant in all two way combinations but was found significant only in three way treatment combinations. The tuber dry matter was maximum in November 1st planting followed by November 16th planting and minimum in October 15th (D_1) planting. Plant spacing showed significant effect on tuber dry matter content which was increased from closer spacing to wider spacing. The superior tuber dry matter was observed at a wider spacing of 75 x 20 cm followed by closer spacing of 60 x 20 cm. As regards to nutrient levels, application of NPK @ 160:80:200 kg ha^{-1} (F_2) noticed the maximum tuber dry matter while, NPK applied @ 120:60:150 kg ha^{-1} (F_1) resulted in the minimum tuber dry matter. Among three way interaction means D x S x F, the highest tuber dry matter recorded from treatment combination $D_2S_2F_2$, which was superior to the rest of treatments except $D_3 S_2 F_2$ whereas the lowest dry matter of 13.74% was noticed in $D_1S_1F_1$ combination.

Tuber specific gravity (g cm^{-3})

According to pooled analysis, tuber specific gravity was significantly high in November 1st planting which was at par with November 16th planting and low in October 16th. Significant differences were noticed due to plant spacing with respect to tuber specific gravity planting (Table 2). The higher tuber specific gravity was observed at a wider spacing of 75 x 20 cm followed by closer spacing of 60 x 20 cm. With regard to NPK levels, NPK applied @ 160:80:200 kg ha^{-1} gave maximum tuber specific gravity and it was at par with NPK applied @ 200:100:250 kg ha^{-1} while, NPK applied @ 120:60:150 kg ha^{-1} recorded the minimum tuber specific gravity. The interaction effect was non-significant in all two way and three way combinations of planting time x spacing x NPK level.

Reducing sugars (%)

From different planting times, November 1st planting took significantly highest reducing sugars whereas October 15th planting produced the least reducing sugars. The spacing had significant effects on reducing sugars and the wide spacing of 75 x 20 cm exhibited significantly higher reducing sugars followed by the spacing of 60 x 20 cm. Similarly, the maximum valves were recorded for reducing sugars at NPK level F_2 and F_3 but both are statically at par while, minimum reducing sugars were found due to the application of NPK level F_1. The interaction effect was non-significant in all two way combinations but was found significant only in three way combination due to planting times x spacing x NPK level (Table 3) and the quantity of reducing sugars was found to be at the highest with $D_2 S_2 F_2$ combination (November 1st planting + 75 x 20 cm spacing + NPK @ 160:80:200 kg ha^{-1}) which was superior to the rest of treatments except $D_2 S_1 F_2$ and the lowest reducing sugars were observed in $D_1 S_1 F_1$ combination (October 16th planting + spacing 60 x 20 cm + NPK @ 120:60:150 kg ha^{-1}).

Total sugars (%)

Total sugars did not differ significantly due to two way interaction effects between D x S, D x F, S x F but it was found significant in case of three way interaction between D x S x F (Table 3).

Table.1 Effect of planting dates, spacing, NPK levels and their interactions on TSS, protein content and ascorbic acid content in potato (pooled)

Factors		Total Soluble Solids (^{o}Brix)				Protein content (mg 100g^{-1})				Ascorbic acid content (mg 100g^{-1})			
Spacing (S)		Planting dates (D)				Planting dates (D)				Planting dates (D)			
		D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
S_1		5.12	6.18	5.35	5.55	6.69	7.67	7.14	7.17	8.40	9.04	8.77	8.74
S_2		5.31	6.46	5.77	5.85	7.26	8.58	7.88	7.91	8.41	9.17	9.10	8.89
Mean		5.21	6.32	5.56	-	6.97	8.12	7.51	-	8.40	9.10	8.94	-
Planting dates (D)		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
D_1		4.84	5.52	5.28	5.21	6.19	7.12	7.61	6.97	8.11	8.46	8.64	8.40
D_2		5.85	6.69	6.43	6.32	7.45	8.08	8.84	8.12	8.76	9.55	8.99	9.10
D_3		5.15	5.87	5.67	5.56	6.86	7.53	8.15	7.51	8.63	9.18	9.00	8.94
Mean		5.28	6.02	5.79	-	6.83	7.58	8.20	-	8.50	9.07	8.88	-
Spacing (S)		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
S_1		5.15	5.87	5.63	5.55	6.58	7.15	7.77	7.17	8.41	9.06	8.73	8.74
S_2		5.41	6.17	5.95	5.85	7.08	8.00	8.64	7.91	8.59	9.07	9.02	8.89
Mean		5.28	6.02	5.79	-	6.83	7.58	8.20	-	8.50	9.07	8.88	-
D x S x F		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	-	F_1	F_2	F_3	-	F_1	F_2	F_3	-
D_1	S_1	4.74	5.44	5.18	-	6.03	6.86	7.17	-	8.12	8.80	8.27	-
	S_2	4.94	5.59	5.39	-	6.34	7.38	8.06	-	8.09	8.13	9.01	-
D_2	S_1	5.68	6.56	6.31	-	7.08	7.52	8.40	-	8.66	9.44	9.00	-
	S_2	6.02	6.81	6.54	-	7.81	8.64	9.28	-	8.87	9.66	8.97	-
D_3	S_1	5.03	5.62	5.41	-	6.63	7.07	7.73	-	8.45	8.95	8.92	-
	S_2	5.27	6.12	5.93	-	7.09	7.99	8.57	-	8.82	9.41	9.08	-
Factors		SE (m) ±		C. D at 5%		SE (m) ±		C. D at 5%		SE (m) ±		C. D at 5%	
D		0.06		0.17		0.09		0.24		0.08		0.24	
S		0.05		0.14		0.07		0.20		0.07		0.19	
F		0.06		0.17		0.09		0.24		0.08		0.24	
D x S		--		NS		--		NS		--		NS	
D x F		--		NS		--		NS		--		NS	
S x F		--		NS		--		NS		--		NS	
D x S x F		0.14		0.41		0.21		0.59		0.21		0.59	

Planting dates (D)
D_1 - October 15th
D_2 - November 1st
D_3 - November 16th

Plant spacing (S)
S_1 - 60 cm x 20 cm
S_2 - 75 cm x 20 cm

Fertilizers levels (F)
F_1 - NPK @ 120:60:150 kg ha^{-1}
F_2 - NPK @ 160:80:200 kg ha^{-1}
F_3 - NPK @ 200:100:250 kg ha^{-1}

NS: Non-significant

Table.2 Effect of planting dates, spacing, NPK levels and their interactions on starch content, tuber dry matter and tuber specific gravity in potato (pooled)

Factors		Starch content (%)				Tuber dry matter (%)				Tuber specific gravity (g/cm^3)			
Spacing (S)		Planting dates (D)				Planting dates (D)				Planting dates (D)			
		D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
S_1		10.57	11.55	11.07	11.06	14.84	16.48	15.78	15.70	1.146	1.175	1.170	1.164
S_2		11.58	12.53	11.72	11.95	16.01	17.86	16.66	16.84	1.191	1.208	1.190	1.196
Mean		11.07	12.04	11.40	-	15.43	17.17	16.22	-	1.169	1.192	1.180	-
Planting dates (D)		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
D_1		9.99	11.74	11.49	11.07	14.21	16.47	15.60	15.43	1.164	1.177	1.164	1.169
D_2		11.00	12.89	12.23	12.04	15.50	18.74	17.28	17.17	1.175	1.209	1.191	1.192
D_3		10.55	12.28	11.35	11.40	14.64	17.92	16.09	16.22	1.164	1.193	1.182	1.180
Mean		10.51	12.31	11.69	-	14.78	17.71	16.32	-	1.168	1.193	1.179	-
Spacing (S)		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
S_1		10.08	11.69	11.42	11.06	14.37	16.96	15.77	15.70	1.159	1.169	1.164	1.164
S_2		10.95	12.93	11.96	11.95	15.20	18.46	16.87	16.84	1.177	1.217	1.195	1.196
Mean		10.51	12.31	11.69	-	14.78	17.71	16.32	-	1.168	1.193	1.179	-
Interaction of D x S x F		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	-	F_1	F_2	F_3	-	F_1	F_2	F_3	-
D_1	S_1	9.25	11.35	11.09	-	13.74	15.84	14.94	-	1.152	1.142	1.144	-
	S_2	10.72	12.13	11.89	-	14.68	17.10	16.25	-	1.176	1.213	1.185	-
D_2	S_1	10.82	11.98	11.86	-	15.04	17.80	16.61	-	1.166	1.187	1.173	-
	S_2	11.19	13.81	12.60	-	15.96	19.68	17.94	-	1.184	1.230	1.210	-
D_3	S_1	10.16	11.73	11.32	-	14.33	17.23	15.77	-	1.158	1.178	1.174	-
	S_2	10.94	12.84	11.39	-					1.170	1.209	1.190	-
Factors		SE (m) ±		C. D at 5%		SE (m) ±		C. D at 5%		SE (m) ±		C. D at 5%	
D		0.13		0.37		0.23		0.47		0.006		0.018	
S		0.10		0.30		0.19		0.38		0.005		0.015	
F		0.13		0.37		0.23		0.47		0.006		0.018	
D x S		--		NS		--		NS		--		NS	
D x F		--		NS		--		NS		--		NS	
S x F		--		NS		--		NS		--		NS	
D x S x F		0.31		0.89		0.56		1.40		--		NS	

Planting dates (D)
D_1 - October 15th
D_2 - November 1st
D_3 - November 16th

Plant spacing (S)
S_1 - 60 cm x 20 cm
S_2 - 75 cm x 20 cm

Fertilizers levels (F)
F_1 - NPK @ 120:60:150 kg ha^{-1}
F_2 - NPK @ 160:80:200 kg ha^{-1}
F_3 - NPK @ 200:100:250 kg ha^{-1}

NS: Non-significant

Table.3 Effect of planting dates, spacing, NPK levels and their interaction on reducing sugars, total sugars and non- reducing sugars contents in potato (pooled).

Factors		Reducing sugars (%)				Total sugars (%)				Non-reducing sugars (%)			
Spacing (S)		Planting dates (D)				Planting dates (D)				Planting dates (D)			
		D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
S_1		4.46	4.94	4.67	4.69	6.69	7.30	7.00	7.00	2.23	2.37	2.33	2.31
S_2		4.70	5.18	4.96	4.95	7.12	7.79	7.45	7.45	2.42	2.61	2.49	2.51
Mean		4.58	5.06	4.81	-	6.90	7.55	7.22	-	2.32	2.49	2.41	-
Planting dates (D)		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
D_1		4.25	4.79	4.71	4.58	6.38	7.22	7.11	6.90	2.13	2.44	2.41	2.32
D_2		4.64	5.47	5.07	5.06	6.97	8.13	7.54	7.55	2.33	2.67	2.47	2.49
D_3		4.44	5.00	5.00	4.81	6.69	7.56	7.43	7.22	2.25	2.56	2.43	2.41
Mean		4.44	5.08	4.93	-	6.68	7.64	7.36	-	2.24	2.56	2.43	-
Spacing (S)		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
S_1		4.33	4.90	4.84	4.69	6.49	7.33	7.17	7.00	2.16	2.43	2.33	2.31
S_2		4.55	5.27	5.02	4.95	6.86	7.94	7.55	7.45	2.31	2.68	2.53	2.51
Mean		4.44	5.08	4.93	-	6.68	7.64	7.36	-	2.24	2.56	2.43	-
D x S x F		Fertilizers levels (F)				Fertilizers levels (F)				Fertilizers levels (F)			
		F_1	F_2	F_3	-	F_1	F_2	F_3	-	F_1	F_2	F_3	-
D_1	S_1	4.18	4.61	4.60	-	6.25	6.95	6.87	-	2.07	2.34	2.27	-
	S_2	4.31	4.97	4.81	-	6.50	7.50	7.35	-	2.20	2.53	2.54	-
D_2	S_1	4.57	5.30	4.94	-	6.83	7.78	7.30	-	2.27	2.48	2.36	-
	S_2	4.72	5.63	5.21	-	7.10	8.49	7.78	-	2.38	2.86	2.58	-
D_3	S_1	4.24	4.79	4.97	-	6.39	7.27	7.33	-	2.15	2.48	2.37	-
	S_2	4.63	5.20	5.04	-	6.98	7.85	7.52	-	2.35	2.65	2.48	-
Factors		SE (m) ±		C. D at 5%		SE (m) ±		C. D at 5%		SE (m) ±		C. D at 5%	
D		0.05		0.15		0.07		0.19		0.03		0.09	
S		0.04		0.12		0.05		0.15		0.02		0.07	
F		0.05		0.15		0.07		0.19		0.03		0.09	
D x S		--		NS		--		NS		--		NS	
D x F		--		NS		--		NS		--		NS	
S x F		--		NS		--		NS		--		NS	
D x S x F		0.13		0.35		0.16		0.46		0.07		0.21	

Planting dates (D)
D_1 - October 15th
D_2 - November 1st
D_3 - November 16th

Plant spacing (S)
S_1 - 60 cm x 20 cm
S_2 - 75 cm x 20 cm

Fertilizers levels (F)
F_1 - NPK @ 120:60:150 kg ha^{-1}
F_2 - NPK @ 160:80:200 kg ha^{-1}
F_3 - NPK @ 200:100:250 kg ha^{-1}

NS: Non-significant

Table.4 Weekly meteorological data recorded during crop period from October-2018 to February-2019 and October 2019 to February-2020 at College of Horticulture, Venkataramannagudem

Std. week No.	Weeks	Rainfall (mm)		Temperature (°C)				Relative Humidity (%)			
				2018		2019		2018		2019	
		2018	2019	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
42	15 Oct - 21 Oct	0	0	35.86	23.57	34.50	22.67	94.43	41.86	93.67	40.33
43	22 Oct - 28 Oct	0	101.6	35.86	23.57	34.86	22.29	90.71	44.14	94.57	44.29
44	29 Oct - 04 Nov	9.10	0	33.66	22.57	33.86	21.14	89.43	39.43	92.14	42.57
45	05 Nov - 11 Nov	0	0	34.86	22.29	34.29	22.71	93.86	36.86	93.00	44.71
46	12 Nov - 18 Nov	0	0	34.57	21.86	33.86	23.29	86.43	35.71	86.86	37.86
47	19 Nov - 25 Nov	0	0	34.71	23.71	33.86	23.29	83.86	37.29	86.86	37.86
48	26 Nov - 02 Dec	0	0	32.71	19.57	33.00	22.57	84.43	36.71	89.14	41.00
49	03 Dec - 09 Dec	0	0	32.29	22.43	31.57	20.00	84.00	35.57	83.00	36.00
50	10 Dec - 16 Dec	0	0	28.56	19.71	31.86	20.57	88.00	36.14	86.86	38.43
51	17 Dec - 23 Dec	48.3	0	28.29	19.43	31.57	21.14	95.00	43.14	90.14	39.43
52	24 Dec - 30 Dec	0	0	29.71	19.71	31.14	20.57	95.71	41.57	89.57	40.57
01	31 Dec - 06 Jan	0	7.10	28.71	18.86	30.14	21.29	93.57	43.29	85.57	39.00
02	07 Jan - 13 Jan	0	0	29.29	18.14	28.86	20.57	94.00	42.71	94.57	45.43
03	14 Jan - 20 Jan	0	0	29.86	18.00	29.71	19.57	94.86	40.00	93.43	47.29
04	21 Jan - 27 Jan	0	0	30.71	19.00	32.57	21.00	95.86	42.29	93.29	43.43
05	28 Jan - 03 Feb	25.7	0	30.57	20.57	32.29	21.57	95.86	44.00	94.86	47.14
06	04 Feb - 10 Feb	0	1.00	31.14	22.00	32.14	21.71	90.86	40.71	93.43	46.57
07	11 Feb - 17 Feb	0	0	31.71	20.86	32.43	20.57	93.00	42.71	91.86	46.29
08	18 Feb - 24 Feb	0	0	34.29	22.29	32.71	21.00	94.57	43.71	93.29	45.71
09	24 Feb - 28 Feb	0	0	33.25	22.00	33.17	21.50	91.75	42.00	91.67	45.67

The total sugars was significantly more in November 1st planting and low in October 16th planting. Among spacing, significantly superior total sugars was recorded from a spacing of 75 x 20 cm followed by spacing 60 x 20 cm. Respect to nutrition levels, the highest and lowest total sugars were produced when NPK was applied @ 160:80:200 kg ha^{-1} and 120:60:150 kg ha^{-1}, respectively. Among three way interactions,

potato planted on November 1st at a spacing of 75 x 20 cm with NPK received @ 160:80:200 kg ha^{-1} recorded the highest total sugars followed by D_3 S_2 F_2 while, October 15th planting at a spacing of 60 x 20 cm with NPK applied @120:60:150 kg ha^{-1} noticed the lowest total sugars.

Non-reducing sugars (%)

Potato planted on November 1st possessed the highest non-reducing sugars which were at par with November 16th planting while; October 15th planting obtained the lowest non-reducing sugars. Non-reducing sugars content was found to vary significantly due to plant spacing levels and 75 x 20 cm spacing took a higher amount of non-reducing sugars as compared to 60 x 20 cm spacing level. NPK levels showed their significant effect on non-reducing sugars which were maximum in medium NPK dose F_2 (160:80:200 kg ha^{-1}) and minimum in low NPK dose F_1 (120:60:150 kg ha^{-1}). The interaction effect on non-reducing sugars was non-significant in all two way combinations but significant only in three way combination of planting time x spacing x NPK level (Table 3) and the combination of above three superior individual factors only exhibited significant superiority *i.e.* the highest non-reducing sugars were recorded with $D_2S_2F_2$ combination and it was superior to the rest of treatments except $D_3S_2F_2$. On the other hand the combination $D_1S_1F_1$ recorded the lowest value for non-reducing sugars.

November 1st plating (D_2) recorded the maximum values for all the quality parameters and this planting had experienced moderately cool temperatures during crop growth (21-32 ^oC) with vigorous vegetative growth and deep green color of foliage which might had favoured higher photosynthetic activity of the plant. So, there was greater accumulation of food material *i.e.* carbohydrates in the tuber resulting in the synthesis of a higher amount of TSS, protein, starch and ascorbic acid contents. These results are in accordance with the findings of Vidya *et al.,* (2013) in garlic, Thirupal *et al.,* (2016) in broccoli, Gomaa (2014) and Al-Abdaly (2016) in potato. The lowest tuber dry matter and specific gravity in October 16th planting (D_1) planting might be due to poor growth on account of higher temperatures during growth (23-34 ^oC) and tuberization periods (22-33 ^oC) which could have resulted in less number of leaves, leaf area and small size tubers and ultimately leading to reduced dry matter production as well as low specific gravity (Al-Abdaly, 2016 and Yogesh *et al*., 2019).

Tuber quality attributes were increased as plants grown at wider plant spacing (75 x 20 cm). This increment might be due to the wider spacing might had provided sufficient room for plant growth and less competition between plant to plant for light and nutrients. The similar results were also noticed by Sunita *et al.,* (2017a) in sweet potato, Rimaljeet (2018) in pea, Getachew *et al.,* (2013) and Dagne *et al.,* (2018) in potato.

As regards to NPK levels, all the quality parameters were found maximum in medium NPK level (F_2: 160N:80P:200K kg ha^{-1}) except protein content; this may be due to the fact that better root growth and spread due to adequate supply of N, P and K which helped in increasing the uptake of nutrients and also translocation of them to the site of action lead to more synthesis of dry matter, TSS, starch, ascorbic acid and sugars contents in tubers. The results are in conformity with those reported by White *et al.,* (1974), Naz *et al.,* (2011) in potato and Sunita *et al.,* (2017b) in sweet potato. Increased protein content in tubers harvested

from F_3 (NPK@200:100:250 kg ha^{-1}) was probably due to increased uptake, assimilation and translocation of nitrogen to the developing tubers. Nitrogen happens to be the essential constituent of proteins (Rajanna *et al.,* 1987).

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