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IMPACT OF CALCIUM NUTRITION ON GROWTH, YIELD AND QUALITY OF POTATO (*Solanum tuberosum*)

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ABSTRACT

Field trials were conducted on sandy loam soil of Adisaptagram Block Seed Farm, Hooghly, West Bengal, India during three consecutive winter seasons of 2009-10, 2010-11 and 2012-13 to study the possibilities of calcium application in different proportions with primary nutrients in potato cultivation under irrigated conditions. The results indicated that all the biometrical parameters showed higher values when the potato crop received recommended dose of fertilizer (RDF) (200:66:124 kg N, P and K ha^{-1} respectively) plus 120 kg Ca ha^{-1} at planting which differed significantly from all other treatments tried in this investigation. Average yield of tuber was maximum (26.25 t ha^{-1}) with RDF + 120 kg calcium application per ha at planting followed by RDF + 80 kg Ca (25.01 t ha^{-1}). Higher dry matter content (15.14%) was obtained with RDF plus split application of Ca i.e. 40 kg at planting and remaining 40 kg at earthing up at par to 80 and 120 kg Ca at planting. On the other hand, yield of skin damaged tuber was higher (1.24 t ha^{-1}) under the treatment having RDF + 40 kg calcium in two equal splits i.e. 20 kg at planting and 20 kg ha^{-1} at earthing up closely followed by RDF + 80 kg Ca ha^{-1}, either single or split application (1.22 t ha^{-1}). Therefore, combined application of RDF + Calcium (80-120 kg ha^{-1}) has been proved to be the best option to get higher tuber yield of potato with good quality characteristics and higher monetary advantage.

Keywords: Calcium, Growth, Potato, Productivity and Quality.

INTRODUCTION

Adequate calcium (Ca) is a critical aspect of the mineral nutrition of potatoes which improves the intake of other plant nutrients specially nitrogen and other trace elements (Fe, Zn, Cu and Mn) by correcting soil pH, and even calcium neutralizes organic acids which may become poisonous to plants (Das, 2000). Potatoes may benefit from added calcium when grown on sandy soils with low calcium levels (Kelling and Schulte, 2004). Calcium is essential plant nutrient for maintaining cell wall activity (Bian et al., 1996) and also promotes root development and growth of the plant as it is involved in root elongation and cell division. Steyn et al. (1992) obtained higher tuber dry mass at the higher gypsum

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application. In contrast, Sterrett and Henninger (1991) reported that tuber yield not to be affected by soil applied Ca. However, El-Beltagy et al. (2002) found tuber yield to increase with increasing calcium to medium levels. Sterrett and Henninger (1991) reported that cooking value of tubers reduced by the presence of necrotic cells (brown discoloured cells). The affected tubers are worthless for consumption since they become very tough after cooking. Collier et al. (1978) demonstrated the Ca application can increase tuber Ca concentration and reduce internal brown spot (IBS). Locascio et al. (1992) opined that yield (per grade) response to Ca is not possible unless soil Ca level is low. In study site, soil Ca content was very low accompanied by high levels of potassium (K). This superabundance of K in the root zone may competitively interfere with Ca uptake. Sud and Sharma (2003) reported that soil application of Ca is more effective than foliar application in increasing the potato yield mainly due to increase in proportion of large and medium sized tubers. Gypsum is widely used to supplement soil Ca (Ozgen et al., 2006). Usually, gypsum is applied as a side-dresser prior to last hilling, and its application has been found to increase tuber Ca and improve grade on low-Ca sandy soil (Simmons et al.,1988). The present study was designed with the specific objectives i) to test the effect of gypsum application on growth of plants; ii) to determine the influence of supplemental Ca nutrition on tuber yield; and iii) to test the effect of several Ca doses with different time of application on tuber Ca-content.

MATERIALS AND METHODS

The field experiment was carried out at Adisaptagram Block Seed Farm, Hooghly, West Bengal, India of Bidhan Chandra Krishi Viswavidyalaya for three consecutive years 2009-10, 2010-11 and 2011-12 during winter season. The soil was loam in texture with pH 6.35, organic carbon 1.60%, Ca and Mg content 0.50 and 0.25 meq 100 g soil^{-1}, respectively and available N-183.26, available P-55.25 and available K-614.03 kg ha^{-1}. Seven different treatment combinations (with and without Ca application) were laid out in a randomized block design and replicated thrice. The treatments were T_1: Recommended dose of fertilizer (200:66:124 kg N, P and K ha^{-1}) + no Calcium, T_2: RDF + 40 kg Ca ha^{-1} at planting, T_3: RDF + 20 kg Ca ha^{-1} at planting and 20 kg ha^{-1} at earthing up, T_4: RDF + 80 kg Ca ha^{-1} at planting, T_5: RDF + 40 kg Ca ha^{-1} at planting and 40 kg ha^{-1} at earthing up, T_6: RDF + 120 kg Ca ha^{-1} at planting and T_7: RDF + 60 kg Ca ha^{-1} at planting and 60 kg ha^{-1} at earthing up. Split application of nitrogen (urea) was done i.e. half at planting time and rest at the time of earthing up (30 days after sowing). Entire amount of phosphatic fertilizer (SSP) was placed in the furrows along the sides of seed pieces and a little below them. Likewise, the full dose of potassium (muriate of potash) was applied as basal (during final preparation). Gypsum (contains 23% Ca and 18% S) was mixed into shallow depth at the time of pre-sowing irrigation and also at earthing up. The medium duration potato variety 'Kufri Jyoti' was sown during third week of November, at a spacing of 60 cm × 20 cm using 25 q tubers ha^{-1} of 40-50 g size as planting material. Harvesting of potato was done at 90 days after planting i.e. during last week of February. Potato produced in each plot was graded into small (0-25 g), semi-medium (26-50 g), medium (51-75 g) and large (> 75 g) size tubers. Counting and weighing of tubers in each grade was done separately to get total tuber yield. Tuber dry matter (%) was estimated by oven-drying 100 g sample at 80°C for initial 4 hours and subsequently at 70°C to a constant weight. The total Ca harvest (kg ha^{-1}) by the tubers was calculated using following equation (Kumar et al., 2007).

Ca harvest (kg ha^{-1}) = (Tuber yield in t ha^{-1} × tuber dry matter in % × tuber Ca content in mg g^{-1} dry weighty) / 1000

Statistical analysis of data was carried out by using MSTAT and critical differences at 5% level of significance.

RESULTS AND DISCUSSION

Soil characteristics

The soil of the experimental field was clay-loam in texture with moderate drainage facilities having medium fertility status and nearly neutral in reaction. Physico-chemical properties of the initial soil are presented in table 1. The value of Ca and Mg content of soil depicts that experimental soil contains very low amount of Ca (0.50 meq 100 g $soil^{-1}$, equivalent to 200 lbs Ca $acre^{-1}$) and low amount of Mg (0.25 meq 100 g $soil^{-1}$, equivalent to 60 lbs Mg $acre^{-1}$). The few instances of Ca deficiency were usually associated with acid soils (pH 5.0 or less) low in organic matter. In other words, soils with low in Ca often have low pH and require lime (Kelling and Schulte, 2004). But the experimental soil had neutral pH (6.35) with high organic matter and available K content, 1.60% and 614.03 kg ha^{-1}, respectively. Values of Ca and Mg content revealed that Ca/Mg ratio (2:1) was within the range for normal crop growth, but Ca content was very low (0.50 meq 100 g $soil^{-1}$, equivalent to 200 lbs Ca $acre^{-1}$). This might be due to repeated high potassium additions may result in neutral soils relatively low in Ca (Kelling and Schulte, 2004).

Growth attributes

Plants grown with Ca showed better growth performance than without Ca plants. All the biometrical parameters showed higher values when the potato crop received recommended dose of fertilizer (RDF) + Ca nutrition as compared to sole RDF without Ca (Table 2). It was also revealed that combined application of RDF + 120 kg Ca ha^{-1} at planting gave higher percentage emergence (93.21), plant height (71.47 cm) and more number of shoots $plant^{-1}$ (4.92) followed by application of RDF + 80 kg Ca ha^{-1} at planting. This may be accorded to the fact that gypsum at higher dose, by improving the pH of the rhizosphere, improved the uptake of nutrients (N, P, K, Ca, S, Cu and Mn) by potato plants. Moreover, it might have also increased the uptake of water by root system. Singh et al. (2001) suggested that the application of gypsum improved growth parameters (number. of stems $hill^{-1}$ and weight of foliage). In contrary, minimum emergence was observed with the treatment having no gypsum application. Singh et al. (2007) and Yadav et al. (2002) also demonstrated minimum emergence of potato tubers (cv. Kufri Sutlej) in no gypsum plots.

Tuber yield

Yield of potato (cv. K. Jyoti) was increased with increase in Ca level while applied in conjunction with RDF. Total tuber yield was maximum (26.25 t ha^{-1}) when the crop received RDF + 120 kg Ca ha^{-1} at planting which was statistically at par with the application of RDF + 80 kg Ca ha^{-1} at planting (25.01 t ha^{-1}) (Table 3). This may be attributed to production of higher number of medium (50-75 g) and large sized tuber (>75g) with soil application of Ca through gypsum. According to other reports, application of gypsum promoted growth of potato plants (Kondo et al., 2001), ultimately resulting in more number of tubers $plant^{-1}$ (Singh et al., 2001) and yield of potato (Yadav et al., 2002; Singh et al., 2007). It is interesting to note that at lower dose of Ca, split application was found superior that basal application (at planting), while at higher dose basal application was better, both with respect to number and yield of tubers. In the present study, RDF + Ca (120 kg at planting) produced more number of tubers ha^{-1} (104953 of 26-50g and 101511 of 51-75g), resulting in higher grade-wise tuber yield (4.78 t ha^{-1} of 26-50g and 8.26 t ha^{-1} of 51-75g). On the other hand, plants without Ca exhibited significant effect on yield attributes and yield of tuber. Comparatively lower yield (both grade-wise and total) was obtained with the application of RDF only (no Ca application) due to less tuber production per unit area. Low or zero calcium level contributes to the onset of necrotic cells (dead cells) visible in the medullary tissues of tuber (Olsen et al., 1996). Tissue necrosis is a physiological disorder called internal brown spot (IBS) which is associated with Ca deficiency in the tubers (Kleinhenz, 2000). Higher incidence of IBS reduces tuber quality and its market value (Bian et al., 1996). The onset of IBS can only be overcome by applying additional Calcium to potato crops (Locascio et al., 1992).

Tuber quality

Quality especially with respect to percent dry matter, skin damaged tuber yield and Ca content in tuber was studied. The results of this study have shown that potato quality could be improved by supplemental Ca fertilization. Significant variation in tuber dry matter content was observed between zero-Ca plants and Ca+ plants, but variation was non-significant between plants grown with varied levels of Ca (Table 4 and Figure 1). Highest tuber dry matter (15.14 %) was obtained with RDF + Ca application in two equal splits (40 kg each at planting and earthing up) which was statistically at par with other treatments except only RDF. Dean (1994) also had a opinion that dry matter content of tubers produced by Ca+ plants was differed significantly from that of without Ca plants, and tuber dry matter content appear to be genetically controlled. However, the yield of skin damaged tuber was increased with the increasing dose of Ca supplied through gypsum. Dubey et al. (2013) also demonstrated that Ca at lower dose (40 kg ha^{-1}) minimized the skin damage of potato tubers (cv. Kufri Pushkar) during harvesting. Further, it was revealed that single application of gypsum at planting produced less skin damaged tubers than split application (Table 4). Method of gypsum application (basal/split) made the difference in skin damaged tuber production. During split application when gypsum come direct contact with tuber skin, it causes more damage to newly developed tubers.

Ca harvest per unit land area

Gypsum application (either basal or split application) did not show marked variation in Ca-content of tubers (Data not shown). Total Ca harvest by potato tuber was higher with 120 kg ha^{-1} followed by 80 kg ha^{-1} (Figure 1). Because of increased tuber yield and high dry matter with 120 kg Ca ha^{-1}, its calcium harvest was higher (98.41% over control i.e. zero-Ca). Under control treatment, though the tuber Ca content per unit dry matter was high, yet because of its low yield and low tuber dry matter, its Ca harvest was much lower than other Ca doses. Present findings were in conformity of Kumar et al. (2007). Clough (1994) opined that Ca concentration in tubers (var. Frontier) increased with increasing pre-plant Ca rate while for 'Russet Burbank' cultivar Ca concentration was increased as side-dressed Ca rate increased, with less brown spot. Calcium accumulation in tuber was more with Ca+ plants than zero-Ca plants. This may be accorded to the fact that gypsum as a source of Ca is believed to increase the amount of accumulated Ca content in the tubers and improve the quality (Kratzke and Palta, 1985 and Spillman, 2003). Results of the two years study showed that gypsum application did not consistently influence tuber Ca-content which might be due to the lower amount of gypsum (40-120 kg ha^{-1}) applied in this study but in other cases gypsum response for tuber Ca occurred only when more than 200 kg Ca ha^{-1} was applied (Simmons and Kelling, 1987; and Simmons et al., 1988). Kleinhenz et al. (1999) also obtained a similar response to 168 kg Ca ha^{-1} applied from gypsum.

Correlation study

Linear correlation analysis (Figure 2a and 2b) revealed that tuber yield was high-positively correlated with dry matter (R^2 = 0.763) while enjoyed low-positive correlation with skin damaged tuber yield (R^2 = 0.560) as indicated by the slopes and intercepts of the respective equations.

y = 8.401 + 1.125 dry matter (R^2 = 0.763) (Eqn. 1)

y = -1.081 + 0.090 skin damaged tuber yield (R^2 = 0.560) (Eqn. 2)

The slope of the Eqn. 1 indicated that rate of increase in tuber yield per unit increase in dry matter was 1.125 t ha^{-1}. The results revealed that tuber yield of potato is largely dependent on tuber dry matter content, and finally increase in Ca level enhanced tuber dry matter and produced higher tuber yield. The data also suggest that with the increase in Ca level tuber yield increases but skin damaged tuber production was increased in lesser amount (Eqn. 2).

Economics

The present study also showed that the profitability of Ca nutrition in potato was more than without Ca (Table 5). Maximum net return (Rs. 66,196.0 ha^{-1}) and benefit: cost ratio (2.02) was obtained with potato crops at higher Ca dose (120 kg ha^{-1}). With the same level of Ca application Dubey et al. (2013) obtained more net return (Rs. 1,03,900.0 ha^{-1}) for potato cv. Kufri Pushkar.

CONCLUSION

Results of the experiment showed that potato cultivar Kufri Jyoti exhibited differences when grown with or without calcium, especially with respect to growth, yield and quality of tuber. Hence, higher yield and quality tubers could be obtained with combined application of recommended dose of fertilizer (RDF) + Calcium (80-120 kg ha^{-1}) under new alluvial zone of West Bengal.

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Table 1. Physico-chemical properties of soil at the start of the experiment (0-15 cm depth)

Sl. No.	Property	Value	Methods
1.	Sand (%)	44.0	Hydrometer method
2.	Silt (%)	30.0	
3.	Clay (%)	26.0	
4.	Textural class	Loam	
5.	pH	6.35	(1:2.5:: Soil : Water)
6.	Organic carbon (%)	1.60	
7.	Ca (meq 100g soil^{-1})	0.50	Complexometric titration method
8.	Mg (meq 100g soil^{-1})	0.25	
9.	Available N (kg ha^{-1})	183.26	Hot alkaline permanganate method
10.	Available P (kg ha^{-1})	55.25	0.5 M $NaHCO_3$ extraction
11.	Available K (kg ha^{-1})	614.03	Neutral N NH_4OAc

Table 2. Effect of calcium on growth attributes of potato cv. Kufri Jyoti

Treatment	Emergence (%)				Plant height (cm)				No. of shoots $plant^{-1}$			
	09-10	10-11	11-12	Pooled	09-10	10-11	11-12	Pooled	09-10	10-11	11-12	Pooled
T_1	93.50	73.00	79.25	83.25	86.41	53.60	58.33	66.11	3.75	3.50	4.00	3.75
T_2	94.50	75.13	82.25	83.96	61.38	59.30	59.95	60.21	5.50	4.25	4.00	4.58
T_3	95.75	80.38	85.63	87.25	61.58	62.53	63.35	62.49	3.50	4.25	3.50	3.75
T_4	95.25	87.25	90.50	91.00	62.74	64.00	66.78	64.51	3.75	5.00	4.75	4.50
T_5	95.50	81.13	89.00	88.54	61.95	70.72	70.32	67.66	3.25	5.25	5.25	4.58
T_6	97.25	91.38	91.00	93.21	71.64	71.22	71.55	71.47	4.25	5.50	5.00	4.92
T_7	95.50	81.38	87.38	88.09	57.70	69.35	71.07	66.04	3.25	5.50	4.25	4.33
SEm±	1.86	1.29	1.03	1.39	3.35	1.39	1.30	2.01	0.47	0.49	0.61	0.52
CD (0.05)	3.90	2.71	2.11	2.91	7.03	2.91	2.85	4.26	0.98	1.02	1.27	1.09

T_1: Recommended dose of fertilizer (200:66:124 kg N, P and K ha^{-1}) + no Calcium, T_2: RDF + 40 kg Ca ha^{-1} at planting, T_3: RDF + 20 kg Ca ha^{-1} at planting and 20 kg ha^{-1} at earthing up, T_4: RDF + 80 kg Ca ha^{-1} at planting, T_5: RDF + 40 kg Ca ha^{-1} at planting and 40 kg ha^{-1} at earthing up, T_6: RDF + 120 kg Ca ha^{-1} at planting and T_7: RDF + 60 kg Ca ha^{-1} at planting and 60 kg ha^{-1} at earthing up

09-10=2009-10, 10-11=2010-2011 and 11-12=2011-12

Table 3. Number and tuber yield of potato (Grade-wise) as influenced by calcium application (pooled data of 3 years)

Treatments	0-25 g tubers		26-50 g tubers		51-75 g tubers		>75 g tubers	
	Number	Yield (t ha^{-1})	Number	Yield (t ha^{-1})	Number	Yield (t ha^{-1})	Number	Yield (t ha^{-1})
T_1	42713	1.01	86071	4.11	79535	6.10	75639	9.83
T_2	52410	1.12	88942	3.80	87644	6.78	93624	9.66
T_3	51237	1.11	101985	4.39	90782	7.32	98046	11.88
T_4	49501	0.70	88920	3.87	97282	7.14	118946	13.01
T_5	51089	1.15	101651	4.44	83265	7.22	100257	12.16
T_6	49434	1.11	104953	4.78	101511	8.26	95969	11.91
T_7	47134	1.10	98372	4.17	83935	6.52	94633	12.12
S.Em (±)	7867	0.14	13685	0.72	12224	1.01	16051	1.64
CD (0.05)	16521	0.29	28737	1.51	25670	2.11	84007	3.47

Table 4. Total yield, dry matter, skin damaged tuber yield and net return as influenced by calcium nutrition

Treatment	Total tuber yield ($t\ ha^{-1}$)				Dry matter (%)				Skin damaged tuber yield ($t\ ha^{-1}$)			
	09-10	10-11	11-12	Pooled	09-10	10-11	11-12	Pooled	09-10	10-11	11-12	Pooled
T_1	22.65	19.44	22.22	21.05	11.28	11.08	11.53	11.30	0.13	0.93	0.87	0.64
T_2	23.04	19.85	22.51	21.80	12.06	12.46	12.29	12.27	0.66	1.16	0.97	0.93
T_3	28.39	21.00	23.99	24.46	15.11	12.81	13.04	13.65	1.50	1.14	1.09	1.24
T_4	27.83	22.51	24.70	25.01	14.52	15.40	14.05	14.66	1.39	1.17	1.01	1.05
T_5	26.19	19.83	26.04	24.02	14.69	15.38	15.35	15.14	1.20	1.31	1.15	1.22
T_6	32.29	23.68	22.77	26.25	14.31	14.71	14.93	14.65	1.07	1.28	1.08	1.14
T_7	26.80	21.03	23.69	23.84	12.53	14.52	14.82	13.96	0.96	1.20	1.08	1.22
SEm±	2.96	0.71	0.62	1.43	1.48	1.35	1.20	1.34	0.18	0.08	0.09	0.12
CD (0.05)	6.20	1.49	1.27	2.99	3.11	2.83	2.71	2.88	0.37	0.16	0.19	0.24

Table 5. Economics of potato production ha^{-1} as affected by Ca nutrition (pooled data of 3 years)

Treat-ment	Cost of cultivation (Rs. ha^{-1})				Gross return (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit : cost ratio
	Seed cost	General cost	Treatment cost	Total			
T_1	24000	25000	14614	63614	105250	41636	1.65
T_2	24000	25000	15094	64094	109000	44906	1.70
T_3	24000	25000	15094	64094	122300	58206	1.91
T_4	24000	25000	15574	64574	125050	60476	1.94
T_5	24000	25000	15574	64574	120100	55526	1.86
T_6	24000	25000	16054	65054	131250	66196	2.02
T_7	24000	25000	16054	65054	119200	54146	1.83

Cost of see tuber, Rs. 1200 t^{-1}, urea, Rs. 6 kg^{-1}, single super phosphate, Rs. 8 kg^{-1}, muriate of potash, Rs. 18 kg$^{-1,}$ gypsum, Rs. 12 kg^{-1}, labour wages @ Rs. 167 man unit^{-1}; produce cost: Rs. 5000 ton

Figure 1. Calcium harvest (kg ha^{-1}) through potato tubers at 90 DAP grown with and without supplemental doses of Ca applied in the soil through gypsum

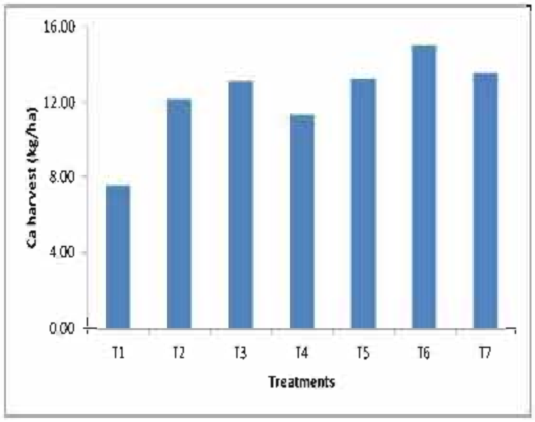
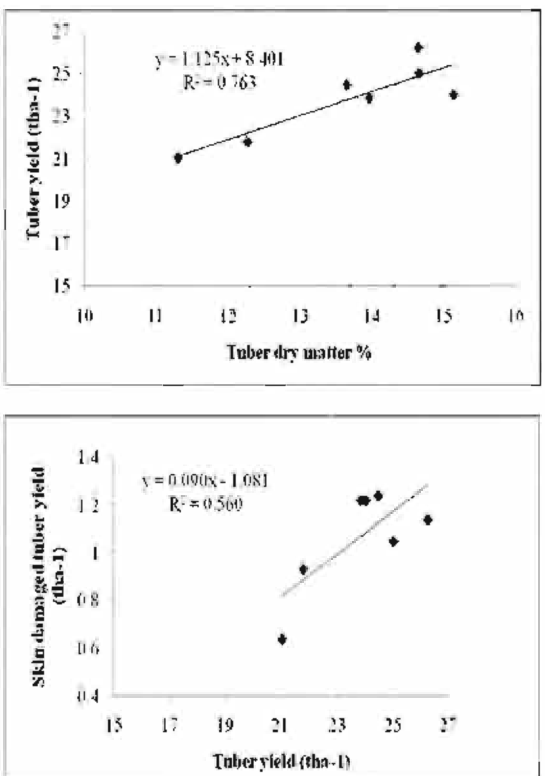


Figure 2. Relationship of tuber yield with [a] tuber dry matter and [b] skin damaged tuber yield



[a]

[b]