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Integrated application of boron and sulphur to improve quality and economic yield in potato

Authors Info

S.K. Singh[1]*, M. Sharma[2], K.R. Reddy[1] and T. Venkatesh[1]

[1]Department of Horticulture, Lovely Professional University, Phagwara -144 411, India

[2]Department of Vegetable Science, Punjab Agriculture University, Jalandhar-141 004, India

*Corresponding Author Email : shailesh.19105@lpu.co.in

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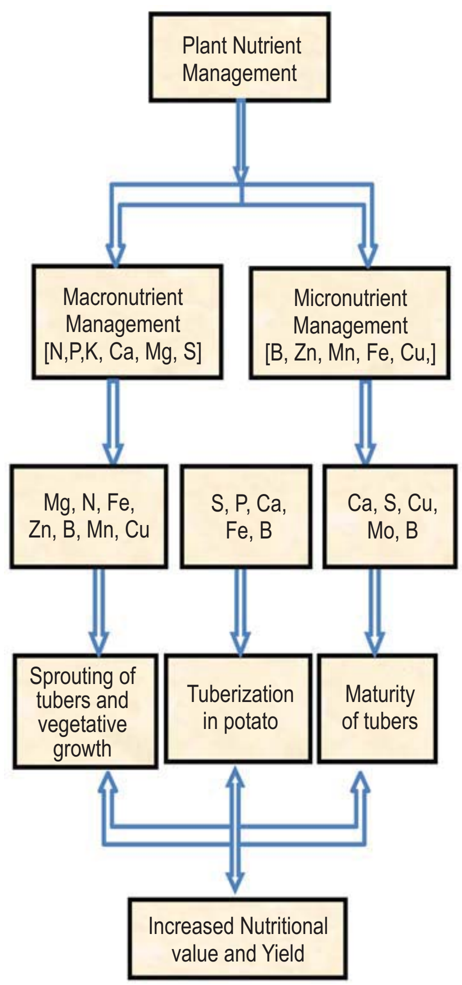
Abstract

Aim : Plant nutrient management through application of sulphur in combination with boron is essential practice to sustain economic and quality yield in potato. The present investigation was performed to determine the economic performance of potato cultivation against integration of sulphur and boron with high grade fertilizers.

Methodology : The field was supplied with recommended dose of N, P and K (120:80:100 kg N, P_2O_5 and K_2O per ha^{-1}). Sulphur (wettable sulphur) and boron (borovin) were applied as both, basal dose and foliar spray at 30 and 60 DAS (days after sowing). Intercultural practices were carried out as per recommendation and observations were recorded on chlorophyll content, yield and economic attributes. Duncan's New Multiple Range Test was applied for statistical analysis of observations.

Results : Foliar application of sulphur or boron was reported to have significant effect on dry matter and starch level in potato tubers, however highest dry matter (26.31%) and starch (71.37%) content was recorded in T_9 (2 foliar sprays of 0.5% borovin and 0.25% sulphur). This was further reported with highest economic yield (360 q ha^{-1}), gross income (Rs. 2, 88, 000), net income (Rs. 2, 14, 900) and B:C ratio (2.940:1), followed by T_3; T_5; T_8 and T_6.

Interpretation : Sulphur and boron application has been reported to bring significant influence on the chlorophyll level of potato plants consequently photosynthetic activity was also influenced. The improved photosynthetic activity had increased the fresh weight of potato tubers, dry matter and starch content of potato tubers when sulphur was applied as foliar application in combination with boron or alone. The tuber yield and B:C ratio was also observed to be significantly increased due to foliar application of sulphur alone or in combination with boron.



Introduction

Potato (*Solanum tuberosum*), a solanaceous crop, bears underground tuber as edible fraction which is a modified stem. Tubers are starchy and contain fair amount of vitamins, minerals, carotenoids and natural phenols. Potato is rich source of carbohydrate and predominant part of this carbohydrate is starch. Potato is an intensive crop and requires nutrients at high rate due to higher dry matter production in given area and time as compared to other field crops. Since most of the soils are poor in available nutrients and the crop has shallow and sparse root system, nutrient demand is generally not met by soil.

Proper dose of nitrogen has significant impact on the quality and yield of the potatoes through increased leaf area, photo assimilation and tuber growth (Vaezzadeh and Naderidarbaghshahi, 2012). Phosphorus is required during early phase of growth to enhance rooting and tuber formation, while in later phase it promotes bulk. Potassium is essential for transportation of nutrients, photosynthetic products and assimilatory products from source to sink. Intensive cropping and application of high-grade nitrogenous, phosphatic and potassic fertilizers to achieve optimum productivity in potato can increase the cost of cultivation and may lead to deficiency of secondary macronutrients and micronutrients (Modgal *et al*., 1995). Application of micronutrients can improve economic yield of potato through alteration of major nutrients uptake and utilization. Thus, nitrogen and potassium level in plants might be function of micronutrient application (Almodares *et al*., 2008).

Sulphur is secondary macronutrient and fourth most required element after nitrogen, phosphorus and potassium to sustain the plant growth and yield because of its need in many biochemical reactions (Sud and Sharma, 2002). Improved soil fertility, grain yield and crude protein in grams due to application of sulphur in combination with phosphorous fertilizers has also been reported by Deshbhratar *et al*. (2010). Plants with sulphur deficiency show poor nitrogen, phosphorus and potash assimilation and reduced catalase activity (Nasreen *et al*., 2008). Sulphur deficiency leads to cysteine and leucine deficiency, and hence to poor dry matter production (Eppendorfer and Eggum, 1994). Sulphur application has been reported to improve the availability of micronutrients like iron, zinc, manganese and copper to the plant by lowering soil pH (El-Tantawy and El-Beik, 2009). Regular removal of sulphur from soil have affected S-budget of soil throughout the world (Aulakh *et al*., 1977) so recently there is an increase in awareness about the role of sulphur application on soil (Bloem *et al*., 2004).

Boron is second most widespread and economically important micronutrient which is essential for several growth related parameters. Its requirement is high after 45 days of crop emergence and remain high till crop maturity. It improves calcium absorption and stabilizes calcium in cell wall. Boron reduces the oxidation of phenols and prevent discolouration of tubers. Boron deficiency induces the internal breakdown of tubers in sugarbeet, turnip and potatoes (Brown *et al*., 2002). Approximately, 90% of boron in plants is accumulated in cell walls so it is associated with cell wall formation, functioning and strength (Blevins and Lukaszewski, 1998). Thus, boron deficiency results in extensive branching and poor growth due to loss of apical dominance (Cakmak and Römheld, 1997). Rashid *et al*. (2002) reported the severity of boron deficiency with the advancement of time and confirmed its necessity for plant fertilization. Hopkins *et al*. (2007) had studied the role of boron on tuberization and yield in potato and reported a non-significant increase due to soil or foliar application of boron. Boron does not 't have direct influence on yield or related attributes, however it plays supplementary role when applied with sulpur (Bari *et al*., 2001).

Considering the significance of sulphur and boron fertilizers for growth and yield of potato, the present study was conducted to assess the optimum combination and method of boron and sulphur application for economic yield and potato quality.

Materials and Methods

Study area : The present study was carried out at Lovely Professional University, Jalandhar, Punjab during the year 2015-2016.

Land preparation and sowing of tubers : The land was ploughed with the help of tractor by using cultivar and rotavator to get the fine tilth. The land was levelled and the field was laid out in experimental plots (3m x 2m) as per plan. Seed tubers (30-40g) were removed from cold store 10 days prior to planting and were spread in shade for proper sprouting. The complete dose of phosphorus (80 kg ha^{-1}) and potassium (100 kg ha^{-1}) along with half of recommended dose of nitrogen (120 kg ha^{-1}) was applied at the time of planting. The remaining half dose of nitrogen was applied at the time of earthing.The sprouted seed tubers were planted during 2nd week of October 2015 by dibbling on ridges at the spacing of 60 x 20 cm. Tubers were covered with soil after planting with the help of a spade.

Intercultural practices : Experimental plots were kept free from weeds throughout the crop growth. Earthing up was done along with application of remaining dose of nitrogenous fertilizerat 45 DAS when potato plants were 12–18 cm high. Soil and foliar application of elemental sulphur and boroven as a source of boron was carried out as per treatments (Table 1). Two irrigations, one before seed bed preparation and other after a week, were applied before crop emergence while subsequent irrigation were applied as per requirement. Plant protection measures were adopted as per incidence of insects, pests and disease. Potatoes were dug manually at the end of January 2016.

Chlorophyll content : Total chlorophyll content of leaves was determined at 60 days after emergence. Leaves were rinsed in 85% acetone solution and absorbance was read at 663 nm and 645 nm wavelength. Chlorophyll content was calcutated (Arnon, 1949) and expressed in mg g^{-1} f. wt.

Table 1 : Treatment schedule of boron and sulphur during experimental period on potato in October 2015 - January 2016

Treatments		Application time and methodology
T_1	Borovin (1g m^{-2})	Applied as basal dose during sowing
T_2	Borovin (0.5g m^{-2}) + One foliar spray (0.5% borovin)	Applied as basal dose during sowing and again as foliar spray after 30 days of sowing
T_3	Two foliar sprays (0.5% borovin)	Applied as foliar spray after 30 days and again 60 days of sowing
T_4	Sulphur (0.5g m^{-2})	Applied as basal dose during sowing
T_5	Sulphur (0.25g m^{-2}) + One foliar spray (0.25% sulphur)	Applied as basal dose during sowing and again as foliar spray after 30 days of sowing
T_6	Two foliar sprays (0.25% sulphur)	Applied as foliar spray after 30 days and again 60 days of sowing
T_7	Borovin (0.5g m^{-2}) + sulphur (0.25g m^{-2})	Applied as basal dose during sowing
T_8	Borovin (0.5g m^{-2}) + sulphur (0.25g m^{-2}) + Two foliar spray (0.5% borovin and 0.25% sulphur)	Applied as basal dose during sowing and again as foliar spray after 30 days of sowing
T_9	Two foliar sprays (0.5% borovin and 0.25% sulphur)	Applied as foliar spray after 30 days and again 60 days of sowing
T_{10}	Control	Boron and sulphur was not applied

Table 2 : Yield related attributes of potato after different treatment schedule of boron and sulphur

Treatments	Fresh weight of potato tuber (in g $plant^{-1}$)	Volume (cc)	Specific gravity (g cc^{-1})	Average yield (kg $plot^{-1}$)
T_1	515.00^{bc}	505.00^{b}	1.020^{b}	11.80^{b}
T_2	595.00^{bc}	580.00^{ab}	1.025^{b}	14.00^{ab}
T_3	795.00^{a}	741.67^{a}	1.077^{b}	21.50^{a}
T_4	641.00^{b}	490.00^{b}	1.320^{a}	15.00^{ab}
T_5	765.00^{ab}	735.00^{a}	1.041^{b}	20.50^{a}
T_6	740.00^{ab}	695.00^{a}	1.077^{b}	19.80^{a}
T^7	472.50^{c}	455.00^{b}	1.037^{b}	10.60^{b}
T^8	670.00^{ab}	665.00^{ab}	1.007^{b}	20.40^{a}
T_9	786.67^{ab}	715.00^{a}	1.106^{b}	21.60^{a}
T_{10}	470.00^{c}	453.50^{b}	1.036^{b}	9.20^{b}
GM	645.02	603.52	1.075	16.44
SEm(±)	51.509	58.309	0.042	2.13
CD	153.05	173.25	0.124	7.65
CV	13.832	16.734	6.712	0.69

Yield related attributes : Tubers from each randomly selected plant were taken to determine fresh weight, volume and specific gravity. The fresh weight (g $plant^{-1}$) of tubers was taken by using electric balance while volume was taken by using measuring cylinder and average was calculated. Specific gravity was calculated and expressed as g cc^{-1}. Average yield per plot was determined by taking weight of potato tubers harvested from each plot and was further converted to per hectare yield.

Chemical composition of potato tuber : The harvested tubers were chopped as cubes and dried in sun then oven at 65°C for 72 hrs to achieve constant weight. The dry matter content was determined by means of drier method and starch content were determined by spectrophotometric method described by Chopra and Kanwar (1976).

Economic analysis : The cost of cultivation was determined by using all inputs as per treatments and the market price while gross monetary returns in rupees per hectare was calculated on the basis of potato yield and prevailing market price of potato. The net income and benefit-cost (B: C) ratio was calculated.

Statistical analysis : The significance of various treatments under study was analyzed through New Multiple Range Testing proposed by Duncan (Gomez and Gomez, 1984).

Results and Discussion

The observation recorded on chlorophyll content (Fig. 1) of potato leaves justified significant effect of foliar application of sulphur and boron. All treatments were reported with high level of chlorophyll in fresh weight of leaves in comparison to control (T_{10}) except T_4, however highest chlorophyll was reported in T_3 (11.57095 mg g^{-1}) followed by T_9 (8.20048 mg g^{-1}), T_8 (6.64002 mg g^{-1}) and T_6 (6.36794 mg g^{-1}). High level of chlorophyll in plants supplied with sulphur or/and boron might be associated with their ability to lower the toxic effect of heavy metals present in soil. Yadav *et al*. (2008) had confirmed that application of boron reduces chlorophyll degradation in radish leaves by lowering nikle toxicity. The increased value of chlorophyll in potato leaves due to application of sulphur has also been reported by Padhi *et al*. (2013). However, lower value of chlorophyll content in T_4 in the present investigation does not support its high value as a function of boron or sulphur. This variation may be due to variation in absorption of nitrogen and potassium containing fertilizers. Al-Moshileh *et al*. (2005) observed a positive influence of potassium sulphate application on chlorophyll concentration.

All the treatments (Table 2) resulted in higher fresh weight of tubers in comparison to control. The highest fresh weight (795.00g) of potato tubers per plant was reported in T_3 which was significantly higher than T_1, T_2, T_4, T_7 and T_{10} and was closely followed by T_9 (786.67 g), T_5 (765.00 g) and T_6 (740.00g).

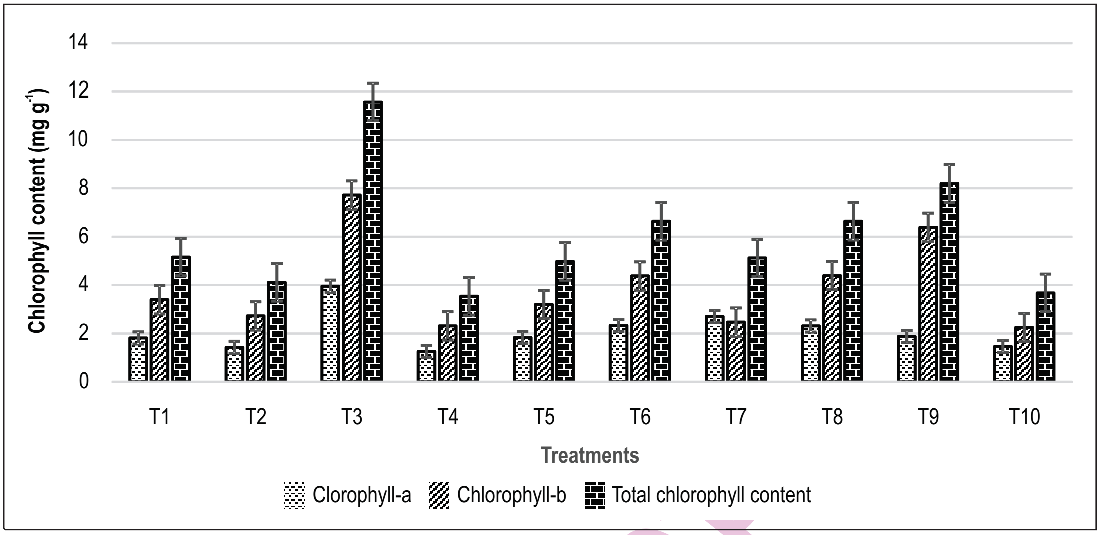


Fig. 1 : Variation in chlorophyll concentration of potato leaves measuredafter 60 days of tuber plantingunder different treatment schedule of boron and sulphur. Values are mean of three replicates ± SD

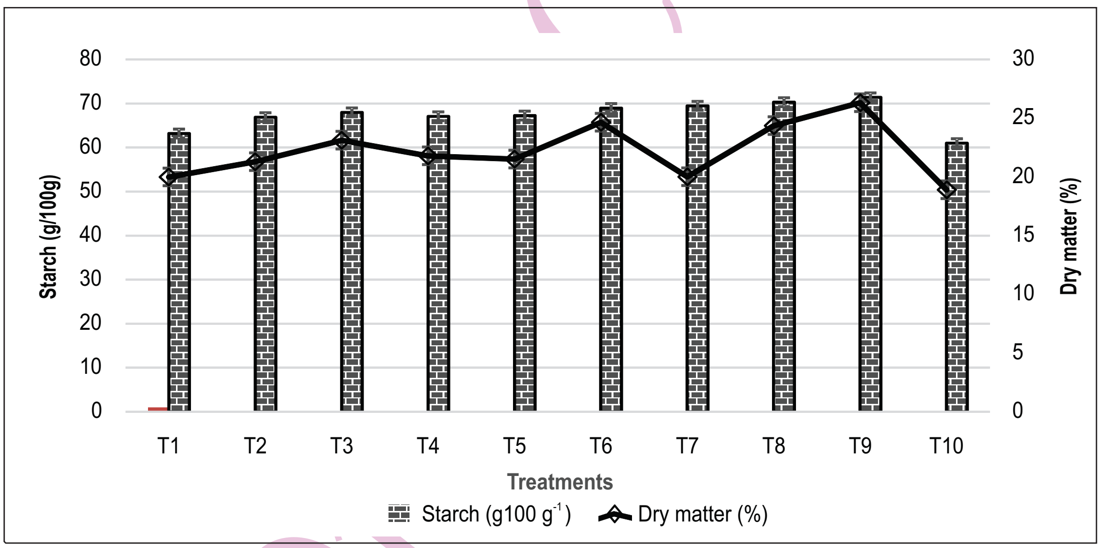


Fig. 2 : Variation in starch and dry matter content of potato tubersunder different treatment schedule of boron and sulphur. Values are mean of three replicates ± SD

Similarly, highest volume (741.67cc) of potato tubers of a plant was reported in T_3 followed by T_5 (735.00 cc), T_9 (715.00 cc) and T_6 (695.00 cc). The specific gravity was reported to be highest in T_4 (1.320g^{-1} cc) which was significantly higher than all other treatments. The significantly high per plot marketable yield was reported in T_9 (21.60 kg) followed by T_3 (21.50 kg), T_5 (20.50 kg), T_8 (20.40 kg) and T_6 (19.80 kg) while the lowest was reported in T_{10} (9.20 kg). The high value of fresh weight per plant, volume of tuber, specific gravity and marketable yield per plot in these treatment was due to higher rate absorption or uptake of major nutrients like N, P and K by the plants (Sud *et al*., 1990; Sud, 2006) which in turn improved plant metabolism and photosynthetic rate as well. This clearly reflects the positive influence of boron and/or sulphur application on the yield related attributes. The present proposal is being confirmed with the findings of Sud and Sharma (2002) who had reported potato tuber yield as function of sulphur level applied. Lalitha *et al*.(2002) had also confirmed about increased tuber yield and bulking due to application of sulphur in potato. Dabhi *et al*. (2004) and Sankaran *et al*. (2005) have also reported increased uptake of nutrients in presence of sulphur and yield in onion. Improvement in potasium and calcium uptake due to foliar application of boron had also been reported by Reinbott and

Table 3 : Economic yield and Benefit- Cost analysis of potato cultivation after different treatment schedule of boron and sulphur

Treatments	Average economic yield (q ha^{-1})	Cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	Benefit: Cost Ratio
T_1	196.67	73,500	157,336	83,836	1.141:1
T_2	233.33	73,250	186,664	113,414	1.548:1
T_3	358.33	73,000	286,664	213,664	2.927:1
T_4	250.00	72,700	200,000	127,300	1.751:1
T_5	341.67	72,650	273,336	200,686	2.768:1
T_6	330.00	72,600	264,000	191,400	2.636:1
T_7	176.67	73,100	141,336	68,236	0.933:1
T_8	340.00	73,400	272,000	198,600	2.706:1
T_9	360.00	73,100	288,000	214,900	2.940:1
T_{10}	153.33	72,500	122,664	50,164	0.692:1
Mean	274.00	72,980	219,200	146,220	2.004:1

Blevins (1995) in tomato. Stunted growth and poor yield in boron deficient tomato plants have also been reported by Davis *et al*. (2003), which might be associated with reduced nitrogen uptake by the plant. These results can be further confirmed by the findings of Zaman *et al*. (2011); Klikocka (2011); Pavlista (2010); Farooqui *et al*. (2009) and Zengin *et al*. (2009), respectively.

The result pertaining to dry matter and starch content of potato tubers, presented in Fig. 2 revealed highest dry matter (26.31%) and starch (71.37g 100 g^{-1}) content in T_9 which was significantly better than all other treatments. T_9 was followed by T_6 (24.65%) and T_8 (24.36%) in dry matter content while T_8 (70.27g 100 g^{-1}) and T_7 (69.45g100 g^{-1}) in starch content. The lowest level of dry matter (18.90%) and starch (60.97g 100g^{-1}) content of potato tuber was reported with control (T_{10}) when plants were not supplied with sulphur and boron. The high level of dry matter and starch content in tubers of plant treated with sulphur alone or in combination of boron was due to increased absorption of available soil nutrient and high rate of photosynthesis. This result can be confirmed by the findings of Sharma *et al*. (2011) who had proved significantly high yield and quality of potato tubers in terms of DM, specific gravity, starch content and sugar level due to application of sulphur. Yadav *et al*. (2008) had also reported improvement in sugar mobilization, DNA and protein synthesis in radish with increasing concentration of boron by reducing Ni toxicity. Similar results have been published by Singh *et al*. (1995) and Shahen *et al*.(2013). Bhagvantagoudra and Rokhade (2002) noticed that application of 40 kg sulphur per ha gave highest yield and higher dry matter in cabbage. The plants without application of sulphur and boron (T_{10}) might be suffered with deficiency so dry matter and starch content was lowest (18.90% and 60.97g100g^{-1}, respectively) and can be confirmed by the findings of Eppendorfer and Eggum (1994) and Petitte and Ormrod (1988) in potato due to sulphur deficiency and by Davis *et al.* (2003) in tomato due to boron deficiency.

The economic analysis (Table 3) confirms highest per hectare economic yield (360 quintals), gross income (Rs. 2, 88, 000), net income (Rs. 2, 14, 900) and B: C ratio (2.940:1) in T_9 which is closely followed by T_3 (358.33 quintals, Rs. 2 86 664, Rs 2, 13, 664 and 2.927 : 1, respectively), T_5 (341.67quintals, Rs. 2 73 336, Rs. 2 00 686 and 2.768:1, respectively), T8 (340.00 quintals, Rs. 2, 72, 000, Rs. 1, 98, 600 and 2.706:1, respectively) and T_6 (330.00 quintals, Rs. 2, 64, 00, Rs. 1, 91, 400 and 2.636 : 1, respectively). Soil or foliar application of boron and sulphur in potato provided higher economic yield, net income and benefit-cost ratio which might be associated with higher chlorophyll content and photosynthetic area to improve photosynthetic activity, plant metabolism and dry matter production. Sulphur induced high yield and benefit: cost ratio has been reported by Mitra *et al*. (2006) in summer green gram and by Nepalia (2005) in mustard while boron mediated improvement in yield, quality and economic return has been reported by Singh *et al*. (2005) due to application of 0.25% or 0.50% borax in Ranchi cultivar of papaya. These can be further confirmed by the findings of Raghav *et al*. (2007) and Singh *et al*. (2016).

The present findings thus suggests that application of boron or sulphur alone or in combination had significantly improved per plant yield of potato tuber, dry matter content, starch content, economic yield and net income to more than double.Thus, application of sulphur and boron in different phase of plant growth can be used to improve quality and economic yield in potato.

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References

Almodares, A., R. Taheri, M. Chung and M. Fathi: The effect of nitrogen and potassium fertilizers on growth parameters and carbohydrate contents of sweet sorghum cultivars.*J. Environ. Biol*., **29**, 849-852

(2008).

Al-Moshileh, A.M., M.A. Errebhi and M.I. Motawei: Effect of various potassium and nitrogen rates and splitting methods on potato under sandy soil and arid environmental conditions. *Emir. J. Agric. Sci*., **17**, 01-09 (2005).

Arnon, D.I.: Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris. Plant Physiol*., **24** , 1-15 (1949).

Aulakh, M.S., B. Singh and B.R. Arora : Effect of sulphur fertilization on the yield and quality of potatoes (*Solanum tuberosum* L.). *J. Indian Soc. Soil Sci*., **25**, 182-185 (1977).

Bari, M.S., M.G. Rabbani, M.S. Rahman, M.J. Islam and A.T.M.R. Hoque: Effect of zinc, boron, sulphur and magnesium on the growth and yield of potato. *Pak. J. Biol. Sci*., **4**, 1090-1093 (2001).

Bhagvantagoudra, K.H. and A.K. Rokhade: Effect of sulphur nutrition on yield, quality and its uptake in cabbage. *Karnataka J. Agric. Sci*., **15**, 182-185(2002).

Blevins, D.G. and K.M. Lukaszewski : Boron in plant structure and function. *Annual Rev. a Plant Biol*., **49**, 481-500 (1998).

Bloem, E., H. Silvia and S. Ewald. Influence of nitrogen and sulfur fertilization on the allin content of onions and garlic. *J. Plant Nutr*., **27**, 1827-1839 (2004).

Brown, P.H., N. Bellaloui, M.A. Wimmer, E.S. Bassil, J. Ruiz, H. Hu and V. Römheld : Boron in plant biology. *Plant Biol*., **4**, 205-223 (2002).

Cakmak, I. and V. Römheld : Boron deficiency-induced impairments of cellular functions in plants. *Plant Soil*, **193**, 71-83 (1997).

Chopra, S.L. and J.S. Kanwar : Analytical agricultural chemistry. Kalyani Publishers, Ludhiana, p. 365 (1976).

Dabhi, N.M., M.V. Patel and V.R. Patel : Effect of sources and levels of sulphur on yield and chemical composition of onion in loamy sand. National Seminar on Development in Soil Science: 69th Annual Convention, Hyderabad, India, p. 124 (2004).

Davis, J.M., D.C. Sanders, P.V. Nelson, L. Lengnick and W.J. Sperry: Boron improves growth, yield, quality, and nutrient content of tomato. *J. Am. Soc. Hortic. Sci*., **128**, 441-446 (2003).

Deshbhratar, P.B., P.K. Singh, A.P. Jambhulkar and D.S. Ramteke: Effect of sulphur and phosphorus on yield, quality and nutrient status of pigeonpea (*Cajanus cajan*). *J. Environ. Biol*., **31**, 933-937 (2010).

El-Tantawy, E.M. and A.K. El-Beik : Relationship between growth, yield and storability of onion (*Allium cepa* L.) with fertilization of nitrogen, sulphur and copper under calcareous soil conditions. *Res. J. Agric. Biol. Sci*., **5**, 361-371 (2009).

Eppendorfer, W.H. and B.O. Eggum: Effects of sulphur, nitrogen, phosphorus, potassium, and water stress on dietary fibre fractions, starch, amino acids and on the biological value of potato protein. *Plant Foods Hum. Nutr*.,**45**, 299-313 (1994).

Farooqui, M.A., I.S. Naruka, S.S. Rathore, P.P. Singh and R.P.S. Shaktawat : Effect of nitrogen and sulphur levels on growth and yield of garlic. *Asian J. Food Agro-Indus.,* Special Issues, S18-S23 (2009).

Gomez, K.A. and A.A. Gomez: Statistical procedure for agricultural research. 2^{nd} Edn., John Wiley and Sons, New York (1984).

Hopkins, B.G., V.D. Jolley, B.L. Webb, J. Ellsworth and R. Callahan: Boron fertilization in Potato. In : Western Nutrient Management Conference. Vol. 7, p. 215-218 (2007).

Klikocka, H.: The effect of sulphur kind and dose on content and uptake of micro-nutrients by potato tubers (*Solanum tubersosum* L.). *Acta Sci. Pol., Hortorum Cultus*., **2**, 137-151 (2011).

Lalitha, B.S., K.H. Nagaraj and T.N. Anand: Effect of source propagation, level of potassium and sulphur on potato (*Solanum tuberosum* L.). *Mys. J. Agric. Sci*., **36**, 148-153 (2002).

Mitra, A.K., K. Banerjee and A.K. Pal: Effect of different levels of phosphorus and sulphur on yield attributes, seed yield, protein content of seed and economics of summer greengram. *Res. Crops*, **7**, 404 (2006).

Modgal, S.C., Y. Singh and P.C. Gupta:Nutrient management in rice-wheat cropping system. *Fertiliser News*, **40**, 49-49 (1995).

Nasreen, S., M.M. Haque, M.A. Husain and A.T.M. Farid: Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. *Bangladesh J. Agric. Res*., **32**, 413-420 (2008).

Nepalia, V.: Influence of weed control and sulphur on growth, yield and economics of mustard production. *Research on Crops*, **6**, 35 (2005).

Padhi, S.K., M. Dash and S.C. Swain : Effect of sulphur dioxide on growth, chlorophyll and sulphur contents of tomato. *European Sci. J*., **9**, 465-471 (2013).

Pavlista, A.D.: Early-season applications of sulfur fertilizers to increase potato yield and reduce tuber defects. *Agronomy J*., **97**, 599-603 (2005).

Petitte, J.M. and D.P. Ormrod: Effects of sulphur dioxide and nitrogen dioxide on shoot and root growth of Kennebec and Russet Burbank potato plants. *Am. J. Potato Res*., **65**, 517-527 (1988).

Raghav, M., T. Kumar and S. Kamal : Effect oforganic sources of nutrients on growth,yield and quality of potato. *Progress. Hort*., **39**, 95-100 (2007).

Rashid, A., E. Rafique and J. Ryan: Establishment and management of boron deficiency in field crops in Pakistan: country Report. In : Boron in Plant and Animal Nutrition (Ed.: H.E. Goldbach). Springer Science & Business Media, U.S. pp.339–348 (2002).

Rashid, A., M.M. Mahmood, E. Rafique and K. Farooq: Potato responses to boron and zinc application in a calcareous Udic Ustochrept. In: Advances in Plant and Animal Boron Nutrition: Proceedings of 3^{rd} International Symposium on all Aspects of Plant and Animal Boron Nutrition, Springer Science & Business Media, U.S.,p. 137 (2007).

Reinbott, T.M.and D.G. Blevins: Response of soybean to foliar-applied boron and magnesium and soil-applied boron.*J.Plant Nutr*.,**18**, 179-200 (1995).

Sankaran, K.,C. Bharathi and S. Sujatha: Effect of sulphur fertilization on yield and nutrient uptake by onion in red soil (Uodic Haplustalf). *J. Maharastra Agril. Univ*., **30**, 135-136 (2005).

Shahen, A.M., A.R. Fatma, G.B. Awatef and Y.I. Helmy : The role of sulphur and bio-phosphorus in potato plant growth and its productivity in newly soil. *Res. J. Agric. Biol. Sci*., **9**, 119-126 (2013).

Sharma, D.K., S.S. Kushwah, P.K. Nema and S.S. Rathore: Effect of sulphur on yield and quality of potato. *Int. J. Agric. Res*., **6**, 143-148 (2011).

Singh, D.K., P.K. Paul and S.K. Ghosh: Response of papaya to foliar application of boron, zinc and their combinations. *Res. Crops*, **6**, 277 (2005).

Singh, H., M. Sharma, A. Goyal and M. Bansal: Effect of nitrogen and sulphur on growth and yield attributes of potato (*Solanum tuberosum* L.). *Int. J. Plant Soil Sci*., **9**, 1-8 (2016).

Singh, J.P., R.S. Marwaha and O.P. Srivastava: Processing and nutritive qualities of potato tubers as affected by fertilizer nutrients and sulphur application. *J. Indian Potato Assoc*., **22**, 32-37 (1995).

Sud, K.C. and R.C. Sharma: Sulphur needs of potato under rainfed conditions in Shimla Hills. In: Potato Global Research and Development (Eds.: S.M.P. Khurana, G.S. Shekhawat, S.K. Pandey and B.S. Singh). Shimla, **Vol. 2**, p. 889-899 (2002).

Sud, K.C., J.S. Grewal and S.P. Trehan : Effect of farmyard manure and N on potato (*Solanum tuberosum*) production and phosphorus and potassium availability in hill soils of Shimla. *Ind. J. Agric. Sci*., **60**, 529-532 (1990).

Sud, K.C. : Anionic balance of nitrogen, phosphorus and sulphur in potato leaves under rainfed conditions in Shimla hills. *Potato J*.,

33, 68–73 (2006).

Vaezzadeh, M. and M. Naderidarbaghshahi: The effect of various nitrogen fertilizer amounts on yield and nitrate accumulation in tubers of two potato cultivars in cold regions of Isfahan (Iran). *Int. J. Agri. Crop Sci*., **4**, 1688-1691 (2012).

Yadav, S.S., R. Shukla and Y.K. Sharma: Nickel toxicity on seed germination and growth in radish (*Raphanus sativus*) and its recovery using copper and boron. *J. Environ. Biol*., **30**, 461-466 (2009).

Zaman, M.S, M.A. Hashem, M Jahiruddin and M.A. Rahim: Effect of sulphur fertilization on the growth and yield of garlic (*Allium sativum* L.). Bangladesh *J.Agric. Res*., **36**, 647-656 (2011).

Zengin, M., F. Gökmen, M.A. Yazici and S. Gezgin : Effects of potassium, magnesium, and sulphur containing fertilizers on yield and quality of sugar beets (*Beta vulgaris* L.). *Turk. J.Agric. For*., **33**, 495-502 (2009).