Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 1855-1861
Received: 28-05-2019
Accepted: 30-06-2019

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Effect of sulphur levels in combination of organic and inorganic sources of nutrient on plant growth and yield of potato (*Solanum tuberosum* L.)

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Abstract
The present investigation was carried out to study the effect of levels of sulphur in combination of organic and inorganic sources of nutrient on plant growth and yield of potato (*Solanum tuberosum* L.) during 2017-18 and 2018-19. The experiment was laid out in randomized block design with ten treatments in three replications. The treatment combinations of four levels of S application *i.e.* 30, 60, 90 and 150 kg ha^{-1} in combinatons of 100% RDF and FYM. The study revealed that plant growth and yield of potato crop were significantly influenced by levels of sulphur application during both the years. Plant population per plot remained statistically unchanged (non-significant) under the various treatments. Control treatment recorded maximum root length at all the stages of crop growth during both the years (12.50, 12.25, 15.08, 13.56, 16.65 and 14.14 cm, respectively) as compared to other treatments. Application of 100% RDF + FYM @ 25 t/ha gave higher value of fresh root weight/plant at all the stage of crop growth as compare to other treatments during both the years (1.12, 1.25, 2.24, 1.80, 1.97 and 1.66 g/plant, respectively). Potato fresh haulm, tuber and biological yield/plot (12.0 m^2) were significantly affected due to different treatments of nutrient application during both the years. Application of 100% RDF + FYM @ 25 t/ha + 30 kg S recorded higher fresh haulm yield (19.56 and 17.54/12.0m^2) and treatment 100% RDF NPK + FYM @ 25 t/ha recorded higher fresh tuber yield (43.22 and 45.84 kg/12.0 m^2) and biological yield (62.06 and 63.16 kg/12.0 m$^{2)}$ as compare to other treatments during both the years. This treatment was at par with 100% RDF + FYM @ 25 t/ha + 30 kg S during both the years.

Keywords: Growth, yield, tuber grade, root, shoot ratio and sulphur

Introduction
Sulphur is one of sixteen essential nutrient elements and fourth major nutrient after N, P and K required by plants for proper growth and yield as it is known to take part in many reactions in all living cells [20]. It is required in similar amount as that of phosphorus. It is a building block of protein and a key ingredient in the formation of chlorophyll. It is required for the synthesis of S containing amino acids such as cystine, cysteine and methionine. Without adequate S, crops cannot reach their full potential in terms of yield or protein content. Sulphur deficient plant had poor utilization of nitrogen, phosphorus and potash [17]. Furthermore, Eppendorfer and Eggum (1994) [4] found that S deficiency significantly influenced the amino acid composition of potatoes; the concentration of the S-containing amino acids methionine and cysteine decreased by 30% and 60%, respectively, in S-deficient soil. Potato is not a highly sulphur demanding crop, with the S concentrations ranging from 1.2 to 2.8 g kg-^{1} in the dry matter of tuber and haulm, but considerable amounts of Sulphur can be removed from the soil over years when potato yields are high. Sulphur application has been found to increase yields of potato tubers, improve tuber quality (increased content of protein, starch, carotene, vitamin C, macro-and microelements) and resistance against *Streptomyces scabies* and *Rhizoctonia solani* [11].
Organic sources which helps in plant nutrient supply and increases the physico-chemical properties of the soil like; soil structure, water holding capacity, soil aeration, soil temperature, pH, balance supply of nutrients to plants, slow release of nutrients and increase the humus content of soil. Organic matter also helps in providing food for soil microorganism. This increases activity of microbes which in term, help to convert the unavailable forms of plant nutrients into available forms. The application of inorganic and organic fertilizers is considered essential to produce high tuber yield. To improve productivity, potato plant requires a balanced dose of NPK along with adequate amount of micronutrients and macronutrients like zinc, boron and sulphur. Micronutrients are essential for plant survival and are only needed in small quantities [9].

Materials and Methods

The experiment was conducted during the *Rabi* season of 2017-18 and 2018-19 in an alluvial soil at the research farm of ICAR-Central Potato Research Institute RS, Gwalior (M.P.). The experimental soil was silty-clay-loan in texture, with pH 6.92, EC (0.27 dS/m), organic carbon (0.39%), available N (162.73 kg/ha), available P (16.01 kg/ha), available K (280.66 kg/ha) and available S (11.33 mg/kg). The experiment was laid out in randomized block design with ten treatments in three replications. The treatments consisted of T_1: control, T_2: 100% RDF NPK, T_3: 100% RDF NPK + 30 kg S, T_4: 100% RDF NPK + 60 kg S, T_5: 100% RDF NPK + 90 kg, T_6: 100% RDF NPK + 150 kg S, T_7: 100 % RDF NPK + FYM @ 25 t/ha, T_8: 100% RDF NPK + FYM @ 25 t/ha + 30 kg S, T_9: 100% RDF NPK + FYM @ 25 t/ha + 60 kg S and T_{10}: 100% RDF NPK + FYM @ 25 t/ha + 90 kg S were applied. The tubers were planted at spacing of 60 cm × 20 cm. The gross plot area was 4.2 m × 4.0 m while net area was 3.0 m × 4.0 m. Potato cultivar "Kufri jyoti" was taken as test crop. Standard cultural practices recommended for potato were followed uniformly for all the experimental plots. The recommended dose of N, P_2O_5, K_2O (180:80:120 kg/ha) and S were applied through Urea, DAP (dia-ammonium phosphate), MOP (muriate of potash) and gypsum respectively. The full quantities of phosphorus, potash and half dose of nitrogen were applied as basal at the time of planting. All the three fertilizers used for basal dressing were mixed before application and was placed 5-7 cm below the seed tubers before planting. While, remaining quantity of nitrogen was applied in split dose at earthing-up. Well decomposed organic manure (FYM) and gypsum were applied three days before planting of tubers. Prior to planting, the field was prepared as per the standard procedure and planting was done on 24^{th} October, 2017 and 25^{th} October, 2018. Five potato plants were randomly sampled from the inner rows of the each plot leaving the border rows. The sampled plants were carefully dunged up, the roots thoroughly washed under running water, put in labeled envelop bags and taken to the laboratory where the growth parameters were recorded at 30, 60 DAP and maturity stage. Different yield parameters *viz.* fresh haulm and tuber weight (g)/plant at 30, 60 and maturity and haulm, grade wise tuber, biological yield and grade wise tuber number were recorded from net plot area (12.0 m^2) and expressed in kg. After harvesting the potato crop, grading was performed on the basis of weight and size of tubers. Tubers were graded into four groups viz. <25 g (<3cm), 25-50 g (3-4cm), 50-75 g (4-5cm), >75 g (>5 cm).

Data were analyzed as per standard procedure with 5% probability level as suggested by Gomez and Gomez (1984) [7].

Results and Discussion

Growth parameters

Plant population

Uniform plant density is an important requisite for obtaining higher precision when it is not a variable factor as the treatments. The data (Table 1) shows that the plant population per plot remained statistically unchanged (non-significant) under the different treatments without giving any definite trend at 30 DAS. It is obviously reflect the fact from these data that the planting of potato was done properly, uniformly in each treatment using healthy and viable seed to maintain the better germination and crop stand per unit area. This result was supported by the result of Eugenia (2008) [5].

Table 1: Effect of sulphur levels in combination of organic and inorganic source of nutrients on plant population, root length and root: shoot ratio of potato

Treatments	Plant population/plot at 30 DAP maturity		Root length/plant (cm.) maturity		Root : shoot ratio maturity	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	135.00	134.33	16.65	14.14	0.03	0.03
T_2:100 % RDF NPK	137.00	137.33	13.22	13.78	0.02	0.02
T_3:T_2 + 30 kg S	137.00	138.00	12.40	11.81	0.03	0.02
T_4: T_2 + 60 kg S	133.67	136.00	12.17	13.22	0.02	0.02
T_5: T_2 + 90 kg S	135.67	134.00	11.53	12.78	0.02	0.02
T_6: T_2 + 150 kg S	135.67	136.67	13.63	13.44	0.02	0.02
T_7: T2 + FYM	140.00	139.33	11.97	13.19	0.02	0.03
T_8: T3 + FYM	139.33	136.67	13.08	13.11	0.03	0.02
T_9: T4 + FYM	138.33	138.33	13.67	13.78	0.03	0.02
T_{10}: T5 + FYM	137.00	136.67	13.43	13.67	0.04	0.02
SEm(d)	1.26	1.60	0.40	0.55	0.003	0.002
CD at 5 %	NS	NS	1.18	1.62	0.009	0.006

Note: FYM @ 25t/ha

Root length/ Plant (cm)

In general, the root length increased with the advancement in crop age and reached maximum at maturity due to positive impact of different nutrient application treatment on this parameter. However, effect of different nutrient application treatments have significant upon this parameter during both the years. Control treatment recorded maximum root length at all the stages of crop growth as compare to other treatments (Table 1). It may be possible due to formation of thinner and longer roots in case of nutrient deficiency in control plot. This finding lined with Gaur *et al.* (2017) [6].

Fresh haulm weight/plant (g)

Overall, fresh potato haulm weight (Table 2) increased with the advancement in crop age and reached maximum at 60 DAP (data recorded at 30, 60 DAP and maturity but table contains only at maturity). There was lower value of fresh haulm weight at maturity stage as compare to 60 DAP. This is possible due to starting of abscission, senescence and translocation of food materials from leaves (source) to underground part *viz.* tuber (sink) from 60 DAP to maturity stage. The effect of various treatments with respect to plant fresh haulm weight was found significant at all the stages of crop growth during both the years. Application of 100% RDF NPK + FYM @ 25 t/ha + 30 kg S gave higher value of this parameter at 60 DAP (202.73 and 231.33 g/plant during 2017-18 and 2018-19 respectively) and maturity stage (207.30 g/plant) in 2017-18, except 2018-19 at maturity stage where it was at par with higher fresh haulm weight treatment (100% RDF NPK + FYM @ 25 t/ha + 60 kg S with 212.47 g/plant) and at 30 DAP this treatment was also at par with higher fresh haulm weight treatment during both the years (100% RDF NPK + FYM @ 25 t/ha in 2017-18 and . 100% RDF NPK + FYM @ 25 t/ha + 60 kg S in 2018-19). This increase may be due to higher availability of nutrients owing to combined application of manure and fertilizer, therefore delay in senescence as a result higher fresh haulm weight as compare to fertilizer applied alone and control treatments. The effect of sulphur fertilization appears to be due to vigorous growth of plant as their presence in plant system suggest greater availability of metabolites and nutrients synchronized to meet demand for growth. Synergistic interaction between sulphur and potassium could have increased availability of all nutrients in soils as reported by Chaudhary *et al.* (1981) [2]. This increase might be also due to steady decomposition of FYM and release of nutrients throughout the crop growth period coupled with better assimilation of nutrients. These findings supported by Kumar *et al.* (2013) [12].

Fresh root weight (g)/plant

Different sources and levels of nutrient application had significant impact on root fresh weight/plant at all stages of crop growth (Table 2), (data recorded at 30, 60 DAP and maturity but table contains only at maturity). The fresh weight of root per plant was augmented steadily in all the treatments with the advancement of plant growth up to 60 DAP and further, decrease in the root fresh weight at 60 DAP to maturity stage due to reduction in water content at maturity because of abscission and senescence. Application of 100% RDF + FYM @ 25 t/ha gave higher value of this parameter (1.12 and 1.25 g/plant at 30 DAP, 2.24 and 1.80 g/plant at 60 DAP and 1.97, 1.66 g/plant at maturity stage) at all the stage of crop growth during both the years as compare to other treatments. It could have been possible due to direct effect of FYM on crop growth which encouraged conducive physical environment leading to better aeration, root density and higher supply of absorption of nutrients during all the stages of crop growth.

Table 2: Effect of sulphur levels in combination of organic and inorganic source of nutrients on fresh haulm, tuber and root weight/plant of potato

Treatments	Fresh haulm weight/plant (g)		Fresh tuber weight/plant (g)		Fresh root weight/plant (g)	
	Maturity		Maturity		Maturity	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	95.60	107.33	251.73	233.87	0.77	0.78
T_2:100 % RDF NPK	169.00	136.93	374.80	336.73	1.08	1.01
T_3:T_2 + 30 kg S	139.87	181.60	380.87	415.33	1.78	1.05
T_4: T_2 + 60 kg S	105.87	195.47	380.40	435.87	1.10	1.37
T_5: T_2 + 90 kg S	109.07	143.20	328.93	356.40	1.08	1.25
T_6: T_2 + 150 kg S	141.00	140.00	352.93	398.87	1.20	1.08
T_7: T2 + FYM	191.27	180.87	432.60	516.00	1.97	1.66
T_8: T3 + FYM	207.30	194.63	395.60	478.87	1.90	1.36
T_9: T4 + FYM	184.13	212.47	323.87	450.13	1.97	1.49
T_{10}: T5 + FYM	137.20	186.07	380.53	456.27	1.76	1.39
SEm(d)	11.47	10.89	12.53	14.32	0.07	0.13
CD at 5 %	34.08	32.35	37.22	42.54	0.22	0.38

Note: FYM @ 25t/ha

Root: Shoot ratio

Root: shoot ratio is an important physiological parameter, which gave clear response about root growth of plant in respect to shoot growth. However, it was statistically significant at all the stages of crop growth during both the years (Table 1) (data recorded at 30, 60 DAP and maturity but table contains only at maturity). Maximum value of this parameter was found in control treatment as compare to other treatments at 60 DAP (0.04 and 0.05) during both the years and maturity stage (0.03) in 2018-19. Whereas, at maturity stage treatment 100% RDF + FYM + 90 kg S in 2017-18 (0.04) also gave higher root shoot ratio. This result is possible due to less shoot development owing to insufficiency of nutrients in control treatment. Insufficiency of available nutrients in soil caused for higher root length upto maturity in search of nutrients pool, on the other hand less development of shoot owing to lack of nutrients. These are in line with the findings of Gaur et al. (2017) [6].

Yield parameters

Tuber fresh weight (g)/plant

Overall, tuber fresh weight (Table, 2) increased with the advancement in crop age and reached maximum at maturity stage (data recorded at 30, 60 DAP and maturity but table contains only at maturity). The effect of various treatments with respect to tuber fresh weight was found significant at all the stages of crop growth. Application of 100% RDF NPK + FYM @ 25 t/ha + 30 kg S gave higher fresh tuber weight at 30 DAP during 2017-18 (4.12 g/plant) as compare to other treatments and it was at par with higher tuber fresh weight treatment (100% RDF NPK + FYM @ 25 t/ha) with 3.03 g/plant in 2018-19. This may be due to higher accumulation of food materials as compare to other treatments because application of sulphur increased the rate of photosynthesis resulting in higher accumulation of food material. Application of 100% RDF NPK +FYM @ 25 t/ha gave higher fresh tuber weight at 60 DAP (338.53 and 375.07 g/plant) and maturity stage (432.60 and 516.00 g/plant) as compare to other treatments during both the years and this treatment was at par with 100% RDF NPK + FYM @ 25 t/ha + 30 kg S during both the years. This may be due to higher and balanced availability of essential nutrients to crop plant owing to reduced losses of applied nutrients. FYM also supply beneficial growth regulator to crop plant as a result increasement in physiological process within the plant ultimately higher tuber fresh weight. This result is also supported by Ahmed *et al.* (2015) [1], Meena *et al.* (2013) [14], Mohammed *et al.* (2018) [15] and Narayan *et al.* (2013) [16].

Grade wise number of tuber per plot

Different sources of nutrient application had significant effect on number of tuber (Table 3) under < 25 g grade during 2018-19, whereas effect was non-significant in 2017-18. In 2017-18 100% RDF + 60 kg S gave higher number of tuber (151.33) under this grade. In 2018-19, this treatment was statistically same with higher number of tuber (229.67) treatment (100% RDF + FYM @ 25 t/ha). Application of 100% RDF NPK + FYM @ 25 t/ha + 30 kg S gave higher number of tuber (148.33) under 25-50 g in 2018-19 and 50-75 g grade (115.33) in 2017-18, as compare to other treatments. It was statistically the same with higher value of treatment (100% RDF NPK + FYM @ 25 t/ha + 60 kg S) in 2017-18 under 25-50 g grade and 100% RDF NPK + 60 kg S in 2018-19 under 50-75 g grade (121.00). Application of 100% RDF NPK + FYM @ 25 t/ha gave higher number of tuber (161.33) under >75 g grade during 2018-19, this treatment was at par with higher number of tuber (140.00) treatment (100% RDF + 30 kg S) under > 75 g grade in 2017-18. The result shows combined application of FYM and fertilizer treatment gave more number of tubers as compare to fertilizer alone treatments. This may be due to higher availability of nutrients in combined application as a result, production of higher amount of tuber. These findings also supported by Sayed *et al.* (2015) [19] and Yadav *et al.* (2014) [21]. Application of 100% RDF NPK +FYM @ 25 t/ha + 30 kg S gave higher total number of tuber (748) as compare to other treatments during 2018-19, it was statistically the same with higher value of treatment (100% RDF NPK + 30 kg S) in with 566.00 tubers in 2017-18. This may be due to presence of sulphur in plant nutrition, vigorous growth of plant as their presence in plant system suggest greater availability of metabolites and nutrients synchronized to demand for growth. Synergistic interaction between sulphur and potassium could have increased availability of all nutrients in soils as reported by Chaudhary et al. (1981) [2]. This result supported by Ahmed *et al.* (2015) [1], Koireng *et al.* (2018) [10] and Mohammed *et al.* (2018) [15].

Table 3: Effect of sulphur levels in combination of organic and inorganic so urce of nutrients on on grade wise tuber number of potato

Treatments	Tuber number /plot							
	<25 g		25-50 g		50-75 g		>75 g	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	130.00	158.67	76.67	87.67	78.67	89.00	85.67	68.33
T_2:100% RDF NPK	149.67	195.67	89.00	126.00	101.33	99.67	106.33	109.33
T_3:T_2 + 30 kg S	150.33	173.33	86.33	136.33	101.33	111.33	140.00	137.33
T_4: T_2 + 60 kg S	151.33	229.67	76.33	113.33	98.33	121.00	130.67	122.67
T_5: T_2 + 90 kg S	126.67	162.00	89.00	117.33	104.67	95.33	110.67	126.00
T_6:T_2 + 150 kg S	103.33	231.33	63.67	115.33	102.33	105.00	109.00	127.67
T_7:T2 + FYM	143.00	221.67	84.00	131.00	112.33	104.67	126.33	161.33
T_8:T3 + FYM	132.33	262.67	76.33	148.33	115.33	118.67	115.67	137.00
T_9:T4 + FYM	124.00	194.00	92.00	129.33	113.33	116.00	104.67	139.67
T_{10}:T5+ FYM	109.33	199.33	67.67	133.33	109.67	114.33	105.67	132.00
SEm(d)	11.00	13.76	6.87	7.87	5.65	7.21	8.10	9.93
CD at 5 %	NS	40.88	NS	23.39	16.80	NS	24.07	29.50

Note: FYM @ 25t/ha

Grade wise yield of tuber (kg/plot)

Different sources of nutrient application had significant effect on this parameter during both the years (Table 4), except 25-50 g grade where different treatments showed non-significant effect on tuber yield during both the years.

Application of 100% RDF NPK + 60 kg S gave higher tuber yield (2.94 kg/plot) under < 25 g grade as compare to other treatments during 2018-19 and it was statistically same with higher value of treatment (100% RDF NPK + 30 kg S) with 1.94 kg/plot in 2017-18. Effect of different treatments were non-significant on yield of tuber under 25-50 g grade during both the years, whereas higher tuber yield was recorded in 100% RDF NPK + FYM @ 25 t/ha + 60 kg S (3.15 kg/plot) in 2017-18 and 100% RDF NPK + FYM @ 25 t/ha + 30 kg S (5.87 kg/plot) in 2018-19. Application of 100% RDF NPK + FYM @ 25 t/ha + 30 kg S gave higher tuber yield (8.09 kg/plot) under 50-75 g grade as compare to other treatments during 2017-18 and it was statistically same with higher value (8.03 kg/plot) of treatment (100% RDF NPK + FYM @ 25 t/ha + 60 kg S) in 2018-19. Application of 100% RDF NPK +FYM @ 25 t/ha gave higher tuber yield (20.51 kg/plot) under >75 g grade as compare to other treatments during 2018-19 and this treatment was at par with higher value (18.55 kg/plot) of treatment in 2017-18 (100% RDF NPK + 60 kg S). This may be due to higher transfer rate of accumulated food material as a result gained more food material therefore higher % of tuber under this treatment. [19] and [21]. In general there was increase in large size (>75 g) and medium size (25-50 and 50-75 g) tuber yield with upto 60 kg s/ha, which showed reduction at further high level. These results are line with Sud and Sharma (2002) [20] who reported that increase in tuber yield with increasing sulphur levels may be attributed to its role in better partitioning of the photosynthates in the shoot and tubers. Similarly, Lalitha *et al.* (2002) [13] have also reported significant effect on grade wise tuber yield and increase in bulking rate with sulphur application. But heavy application of sulphur can result in yield reductions [3]. These findings are also in agreement with those of Nasreen *et al.* (2007) [18].

Table 4: Effect of sulphur levels in combination of organic and inorganic source of nutrients on grade wise tuber yield of potato

Treatments	yield of tubers (kg/plot)							
	<25 g		25-50 g		50-75 g		>75 g	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	1.13	1.50	2.98	3.89	5.62	5.70	12.82	8.24
T_2:100 % RDF NPK	1.70	2.43	2.94	4.82	6.32	6.09	15.93	14.38
T_3:T_2 + 30 kg S	1.94	1.99	3.03	5.10	5.39	6.00	15.04	17.69
T_4: T_2 + 60 kg S	1.62	2.94	3.04	4.32	6.01	8.05	18.55	16.13
T_5: T_2 + 90 kg S	1.50	1.81	3.12	5.01	7.35	6.13	13.43	17.82
T_6:T_2 + 150 kg S	0.97	2.21	2.20	4.08	6.60	7.30	11.53	16.66

T_7: T2 + FYM	1.42	2.63	2.77	5.63	7.92	7.16	17.75	20.51
T_8: T3 + FYM	1.52	2.80	2.84	5.87	8.09	7.33	15.49	18.85
T_9: T4 + FYM	1.46	2.17	3.15	4.95	7.50	8.03	14.70	18.65
T_{10}:T5 + FYM	1.51	2.09	2.48	4.75	7.34	7.44	16.06	18.89
SEm(d)	0.17	0.21	0.27	0.40	0.45	0.54	0.99	1.17
CD at 5 %	0.51	0.64	NS	NS	1.33	1.61	2.93	3.48

Note: FYM @ 25t/ha

Fresh yield (kg/plot)

Potato fresh haulm, tuber and biological yield kg per plot were significantly affected due to different treatments of nutrient application during both the years (Table 5). Application of 100% RDF + FYM + 30 kg S recorded higher fresh haulm weight (19.56 and 17.54 kg/plot) during both the years as compare to other treatments. This may be due to presence of S and FYM in plant nutrition, vigorous growth of plant as their presence in plant system suggest greater availability of metabolites and nutrients synchronized to meet demand for growth. Synergistic interaction between sulphur and potassium could have increased availability of all nutrients in soils as reported by Chaudhary *et al.* (1981) [2]. This result supported by Ahmed *et al.* (2015) [1], Koireng *et al.* (2018) [10] and Mohammed *et al.* (2018) [15]. While, Application of 100% RDF NPK + FYM @ 25 t/ha recorded higher fresh tuber yield (43.22 and 45.84 kg/plot) and fresh biological yield (62.06 and 63.16 kg/plot) as compare to other treatments during both the years respectively, this treatment was at par with 100% RDF + FYM + 30 kg S during both the years. This may be due to higher stem number/plant, higher leaves number/plant, and higher total uptake of nutrients under this treatment may be due to combined effect of FYM and fertilizer. Balanced nutrient availability and beneficial effect of FYM helped in increasing the availability of various macro and micronutrients in soil [8]. FYM supplies nutrients in available forms to the plants in right proportion. Uniform and continuous nutrient supply for longer period through biological decomposition along with micronutrients resulted into higher growth and yield attributing characters and ultimately yields. Improvement in tuber yield was observed upto 60 kg S/ha application, which showed reduction at further high level of S application because more availability of sulphur, S is an important component in plant nutrition, might have increased the yield in potato upto a limit, but heavy application of S can result in yield reduction because requirement of S for potato is low and this requirement of crop was fulfilled by FYM and along with low level of S application. S also has antagonistic effect with essential nutrients at higher concentration in soil solution. Therefore, its higher availability in soil solution caused antagonistic effect with other essential nutrients to plants ultimately resulted reduction in yield at higher sulphur application. These results are in line with Sud and Sharma (2002) [20], Lalitha *et al.* (2002) [13] and Narseen *et al.* (2007) [18].

Table 5: Effect of sulphur levels in combination of organic and inorganic source of nutrients on fresh yield (kg/plot) of potato

Treatments	Fresh yield (kg/plot)					
	Haulm		Tuber		Biological	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	8.39	6.73	27.22	21.11	35.61	27.84
T_2:100% RDF NPK	15.98	13.61	36.29	38.69	52.27	52.30
T_3:T_2 + 30 kg S	16.63	14.14	38.01	40.19	54.64	54.33
T_4: T_2 + 60 kg S	16.99	14.05	37.42	40.29	54.41	54.35
T_5: T_2 + 90 kg S	17.98	14.41	36.58	39.56	54.55	53.97
T_6: T_2 + 150 kg S	17.78	15.29	34.26	39.01	52.04	54.30
T_7: T2 + FYM	18.84	17.32	43.22	45.84	62.06	63.16
T_8: T3 + FYM	19.56	17.54	41.13	45.14	60.69	62.68
T_9: T4 + FYM	17.84	16.39	40.45	41.43	58.29	57.82
T_{10}: T5 + FYM	17.51	15.08	40.98	42.11	58.49	57.19
SEm(d)	0.87	0.70	1.08	1.50	1.45	1.53
CD at 5 %	2.57	2.08	3.22	4.45	4.30	4.55

Note: FYM @ 25t/ha

Correlation

Potato tuber yield showed positive and highly significant relationship with root fresh weight/plant at maturity (0.8739**), tuber fresh weight/plant at maturity (0.9476**) and total number of tuber/plot (0.9315**) (Fig 1, 2 and 3).

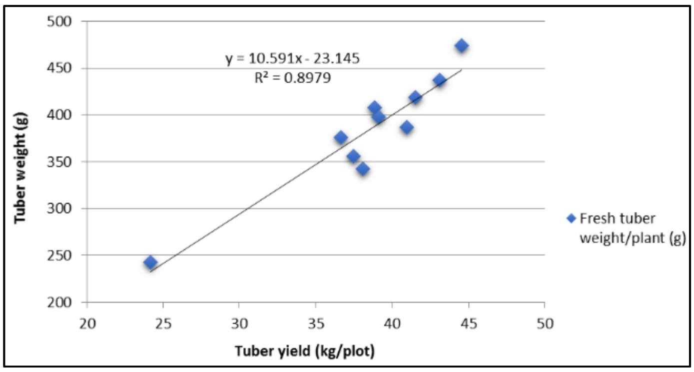

Fig 1: Correlation between tuber yield (kg/plot) and tuber weight (g/plant)

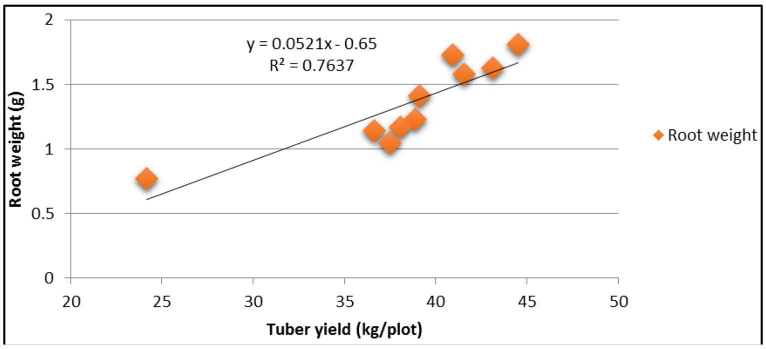

Fig 2: Correlation between tuber yield (kg/plot) and root weight (g)/plant

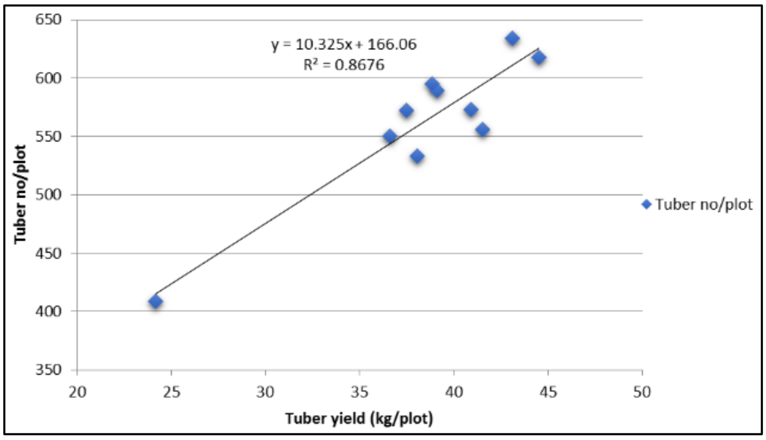

Fig 3: Correlation between tuber yield (kg/plot) and tuber number/plot

Conclusion

Based on two years of field experimentation, it may be concluded that application of sulphur @ 30 kg/ha to potato is sufficient dose for increased growth and yield of potato crop. Treatment 100% RDF NPK + FYM @ 25 t/ha and 100% RDF NPK + FYM @ 25 t/ha + 30 kg S were the better treatment as compare to other treatments in relation to crop yield and soil fertility because requirement of S for potato is low and this requirement of crop was fulfilled by FYM and along with low level of S application. Further, high level of S application resulted reduction in crop yield and soil fertility due to more availability of sulphur. Sulphur also has antagonistic effect with essential nutrients at higher concentration in soil solution.

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