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Bio-Chemical Composition, Nutrient Uptake and Dry Matter Yield of Gram as Affected by Oxalic Acid Industry Waste and Fertilizer Levels in Vertisol

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Pot culture experiments were conducted with three levels of oxalic acid industry waste *i.e.*, 0 g, 6.6 g, and 13.2 g per pot corresponding to three levels of sulphur *i.e.* 0 (S_0), 20 (S_{20}) and 40 (S_{40}) ppm of S, three levels of phosphorus 0 (P_0), 40 (P_{40}) and 80 (P_{80}), ppm of P, two levels of starter dose of nitrogen *i.e.* 0 (N_0) and 20 (N_{20}) ppm of N and seed treatment with (C_1) and without (C_0) rhizobium culture. Results reveal that increasing levels of application of variables significantly increased the dry matter yield of gram (40 DAS) as compared to control. Similar positive increasing trend was also observed in nitrogen, phosphorus, potassium, calcium, magnesium and sulphur uptake at 40 DAS over control.

INTRODUCTION

Disposal of large volume of industry waste poses a big problem and its disposal involves use of financial resources. Proper disposal or recycling of industrial waste is essential to minimise and control enviromental pollution. Oxalic acid is produced from the bark of Saja (*Terminalia termentosa*) tree by treating it with concentrated sulphuric acid. Waste matter obtained by this process is sawdust like material which is acidic in nature (12.5% free acidity), rich in organic matter (45%), calcium (18.5%) and sulphur (13%). Successful use of oxalic acid industry waste as a source of sulphur for many crops has heen previously reported by several workers[1,2]. There is a need to evaluate the utility of this organic waste as a source of sulphur in comparison and in conjucation with inorganic and bio-fertilizers to gram crop.

EXPERIMENTAL

Pot culture experiment was conducted in rabi season of 1990–91 with gram (*Cicer ariethinum*) var. J.G. 315 as a test crop at J.N. Krishi Vishwa Vidyalaya, Jabalpur. The soil used the experiment was a hyperthermic, clay chromustert low in available-N (180 & 168 kg ha^{-1}) available P (4.26 & 3.92 kg ha^{-1}), available S (5.62 & 4.38 kg ha^{-1}) and high in available-K (329 & 386 kg ha^{-1}) having electrical conductivity (0.34 dSm^{-1}) and neutral in reaction (7.2 pH). Experiment consisted of three levels of industry waste *i.e.*, 0, 6.6 & 13.2 g pot^{-1} providing 0 (S_0), 20 (S_{20}) & 40 (S_{40}) ppm S, two levels of starter dose of nitrogen *i.e.*, 0 (N_0) and 20 (N_{20}) ppm N as urea and three levels of phosphorus *i.e.*, 0 (P_0), 40 (P_{40}) & 80 (P_{80}) ppm P applied through mono calcium phsophate. One set of treatment consisted of seeds treated with *Rhizobium* culture (C_1) and other set of seeds was sown as uninoculated (C_0). A basel dose of 30 ppm potassium was given in the form of muriate of potash. Treatments were replicated three times in double split randomised block design. Seeds were sown in ten killogram earthen pot having 36 cm upper, 18 cm lower diameter and 30 cm depth and eight plants were allowed to grow upto maturity. Plant sampling was done at the most critical growth stage for nutrient which is maximum tillaring stage *i.e.*, 40 days after sowing (40 DAS) of crop. Same experiment was repeated in 1991–92 rabi with same soil (fresh) and same treatments.

For uptake study two plant samples were randomly selected from each pot 40 days after sowing of crop. Root portion was cut off and used for nodulation study. Shoot portion was dried in oven at 60°C for 48 h till constant weight was obtained and dry matter weight was noted. After maturity of crop grain and straw yield was recorded. Representative plant and soil samples were processed and digested in diacid mixture of nitric and perchloric acid (5:2). Plant samples were analysed for nitrogen, phosphorus, potassium, calcium, magnesium and sulphur by the common methods used in laboratory[1, 2]. Protein and carbohydrate content in grain samples were determined[3]. Oil content in grain was estimated by extracting it with petroleum ether (60–80%) in soxhlet apparatus. The energy yield was calculated by the usual method[4].

RESULTS AND DISCUSSION

Dry Matter Yield

The data presented in the Table 1 indicate that dry matter production per plant ranged from 1.18 to 2.58 g. Application of 0.20 and 40 ppm S through oxalic acid industry waste along with a basal dose of 30 ppm K per pot significantly increased the dry matter yield and the per cent response was in order of 11.3 & 22.7 and 16.7 & 36.5% respectively over control in 1990–91 and 1991–92. The higher dose of P (80 ppm) gave significantly more dry matter yield over lower levels (40 ppm) and control (0 ppm) during both the years of experimentation. This response of S and P in enhancing the dry matter yield may be due to the fact that experimental soil was low in available S and P[5]. Further, results on dry matter yield showed that there was 15.9 & 21.1% increased in yield with increase in the rate of nitrogen from N_0 to N_{20} whereas 17.3 & 56.7% increase in yield was recorded when seeds were treated with *Rhizobium* culture as compared to uninoculated ones in both the years. Addition of 20 ppm N and seed inoculation might have fulfilled the nitrogen requirement during the initial stages of plant growth[6]. Interaction between (P & S) was found to be significant in 1990–91, while interaction of P and S with nitrogen and *Rhizobium* culture was positive in 1991–92 only. These interactions indicate that oxalic acid industry waste used as a source of sulphur could prove to be markedly beneficial when used along with

P and N as is evident from the percentage reduction in dry matter yield of gram when S is applied alone[7].

Nutrient Uptake

Uptake of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur by gram increased due to addition of nitrogen, phosphorus, seed inoculation and sulphur applied as industry waste in the years 1990–91 and 1991–92 (Table 1). Increase in the uptake of sulphur might be due to increase in dry matter yield and concentration of the nutrients in the crops due to sulphur and other nutrients present in the waste[8]. Application of mono calcium phosphate to gram has shown significant affect on the uptake of above mentioned nutrients. This increase in uptake may be due to fact that industry waste might have contained some amount of unextracted oxalic acid. Upon ionization this oxalic acid might have increased with time resulting in higher release of P from fertilizer and soil[9]. A persual of the data in Table–1 would indicate that gram crop responded well to the application of starter dose nitrogen as for as uptake of nutrients is concerned. The results (Table 1). Further suggest that the use of *Rhizobium* culture, augments the uptake of N,P, K, Ca, Mg and S as compared to control. Higher uptake during 1990–91 and 1991–92 due to above treatments could be attributed to availability of plant nutrients at the initial growth stage of crop because experimental soil was deficient in available N, P and S[10].

Bio-chemical Composition

An increasing trend in protein content was observed due to application of sulphur through oxalic acid industry waste, phosphorus, nitrogen and use of *Rhizobium* culture during both the years. At higher levels, the beneficial effect was more pronounced than at lower levels. S_{40} level was found to be the best as it had resulted in the production of 20.73% and 20.21% protein in grain as against 16.8% and 17.35% in control in 1990–91 and 1991–92 respectively. This might be due to the fact that sulphur containing amino-acids (cystein, cysteine and methionine) which are increased with the sulphur application might have led to high protein content[11]. Increasing the phosphorus supply from P_0 to P_{80} increased the protein content in gram seed. The extent of increase was 3.47 to 9.85% and 2.81 to 4.42% in the first and second years respectively. Earlier reports have also shown that legumes usually make better use of atmospheric nitrogen when phosphorus is applied to the soil as it enhances the protein content of pulses[12]. The percentage of protein was highest (19.25 & 19.35% and 19.35 & 19.38%) with the application of 20 ppm starter dose of N and use of *Rhizobium* culture in both the years has also been observed that improvement in seed protein content occurred with the application of N in the form of urea. When N supply is a limiting factor protein synthesis is depressed[13].

Application of S, P, N and use of *Rhizobium* inoculum marginally enhanced the carbohydrate content in gram in both the years (Table 2). However, the results were more prouned in case of N treatment. When nitrogen supply is a limiting factor, it disturbs the nitrogen metabolism in plant and it may effect the plant succerlence also but when nitrogen supply is sufficient it increase the protein as

TABLE-1
EFFECT OF OXALIC ACID INDUSTRY EFFLUENT, RHIZOBIUM CULTURE, NITROGEN AND PHOSPHORUS ON DRY MATTER YIELD (g pot^{-1}) AND MAJOR NUTRIENT UPTAKE (mg $plant^{-1}$) BY GRAM AT 40 DAS

Treatment	Dry matter yield		Nitrogen uptake		Phosphorus uptake		Potassium uptake		Calcium uptake		Magnesium uptake		Sulphur uptake	
	90–91	91–92	90–91	91–92	90–91	91–92	90–91	91–92	90–91	91–92	90–91	91–92	90–91	91–92
C_0	2.14	1.18	12.51	15.57	3.08	2.82	3.15	2.54	52.72	27.57	4.50	3.77	2.62	1.76
C_1	2.51	1.85	12.57	15.51	4.22	4.93	3.44	3.81	63.52	46.31	6.45	4.56	5.51	3.07
N_0	2.15	1.36	17.01	32.78	3.08	3.31	3.31	2.51	52.33	32.31	4.73	4.24	2.58	2.05
N_{20}	2.49	2.67	19.90	29.39	4.22	4.44	3.78	3.85	62.91	41.57	6.22	4.09	3.55	2.78
P_0	2.04	1.15	11.59	16.53	3.01	2.77	2.33	2.52	48.97	26.92	4.75	3.73	2.51	1.66
P_{40}	2.36	1.53	14.11	23.83	3.70	3.88	2.72	3.40	58.04	37.21	5.77	4.61	3.09	2.45
P_{80}	2.58	1.85	16.44	30.02	4.31	4.96	3.57	4.34	67.34	46.69	5.89	5.65	3.59	3.14
S_0	2.12	1.26	12.28	18.75	3.21	3.07	2.57	2.79	49.92	29.98	5.43	3.80	2.68	1.87
S_{20}	2.36	1.54	14.15	23.65	3.66	3.93	2.81	3.52	59.37	37.87	5.51	4.21	3.08	2.46
S_{40}	2.48	1.72	15.70	28.03	4.01	4.61	2.95	3.97	64.14	42.96	5.30	4.98	3.43	2.92
	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%
C	0.07	0.04	0.42	2.21	0.29	0.16	NS	0.22	2.19	1.94	0.21	0.16	0.36	0.10
N	0.07	0.04	0.42	2.21	0.29	0.16	NS	0.22	2.19	1.94	0.21	0.16	0.36	0.10
P	0.04	0.03	0.50	0.94	0.17	0.10	NS	0.14	1.44	1.21	0.26	0.11	0.18	0.09
S	0.05	0.03	0.43	0.62	0.13	0.11	NS	0.11	1.38	0.96	0.31	0.08	0.11	0.06
P × S	0.08	NS	0.78	1.27	0.24	0.18	NS	0.10	2.36	1.79	0.51	0.15	0.23	0.13
C × N × P	NS	0.06	0.86	2.37	0.32	0.21	NS	0.26	2.86	2.21	NS	0.18	0.35	0.13
C × N × S	NS	0.07	0.80	2.11	0.36	0.22	NS	0.29	2.91	2.49	NS	0.22	0.42	0.18

TABLE-2
EFFECT OF OXALIC ACID INDUSTRY WASTE, RHIZOBIUM CULTURE, NITROGEN AND PHOSPHORUS ON PROXIMATE PRINCIPLE CONTENT (%) AND ENERGY YIELD ($plant^{-1}$) OF GRAM (*Cicer arietinum*)

Treatment	Protein content		Carbohydrate content		Oil content		Energy yield (Kcal.)	
	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92
C_0	17.94	18.60	58.86	59.66	5.54	5.17	43.03	60.73
C_1	19.35	19.38	59.80	62.25	5.70	5.29	45.68	98.91
N_0	18.03	18.61	58.79	60.73	5.54	5.20	42.97	70.06
N_{20}	19.25	19.39	59.87	61.13	5.70	5.26	45.74	89.59
P_0	17.85	18.55	58.95	60.22	5.58	5.13	39.25	62.06
P_{40}	18.47	19.07	59.37	61.18	5.59	5.22	45.66	81.14
P_{80}	19.61	19.37	59.96	61.28	5.69	5.24	50.15	96.20
S_0	18.22	18.53	59.20	60.30	5.55	5.20	40.25	69.66
S_{20}	18.54	19.12	59.37	61.16	5.66	5.23	45.36	81.77
S_{40}	19.59	19.53	59.52	61.41	5.68	5.25	47.44	80.07
	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%	CD 5%
C	0.41	0.28	0.83	1.21	0.25	0.09	—	—
N	0.41	0.28	0.83	1.21	0.25	0.09	—	—
P	0.34	0.24	NS	NS	NS	NS	—	—
S	0.39	0.24	NS	1.11	NS	NS	—	—
P × S	NS	NS	NS	NS	NS	NS	—	—
C × N × P	NS	NS	NS	NS	NS	0.13	—	—
C × N × S	0.65	NS	NS	NS	NS	NS	—	—

well as carbohydrate content in seed[14]. Addition of phosphorus alone or in conjuction with other treatments increased the carbohydrate content in gram seed by 1.12 to 1.21% and 1.42 to 2.26% during both the years of study. Phosphorus is involved in the carbohydrate metabolism. It is a constituent of sugar phosphate. Phosphorus deficiency results in an increased accumulation of free reducing sugar in plant. It is reported that phosphorus levels increase the nitrogenase activity and concentration of sugar in leaves, suggesting improved translocation of reduced nitrogen from leaf to pod which is needed for carbohydrate synthesis in seed[15].

Application of oxalic acid industry waste as a source of sulphur and mono calcium phosphate as a source of phosphorus slightly increased the oil content in gram. Highest oil content was recorded at higher doses of S and P (40 & 80 ppm respectively). However, there was no significant difference at S_{20} and P_{40} levels. Sulphur application increased oil content by 1.07 and 2.54 per cent while, phosphours increased it by 1.97 and 2.14 per cent during both the years respectively. Application of 20 ppm N as a starter dose and use of *Rhizobium* inoculation increased the oil content. The increase in oil content was 3.06 & 2.32% and 3.05 & 1.15% respectively due to use of *Rhizobium* culture and nitrogen application as compared to control in 1990–91 and 1991–92 respectively. The C × N × P interaction showed that graded doses of P or S with definite level of N increased the oil content in gram seed. Beneficial effect of S and P on oil content may be due to increase in linolenic acid content and probably due to increase in glycosides, which on hydrolysis produces higher amount oil. The S and P accelarate the metabolic path way of lenolenic acid synthesis[16].

Addition of industry waste, use of *Rhizobium* culture, nitrogen and phosphorus increased the energy yield per plant during both the years of investigation. The energy release calculation are based on protein, oil and carbohydrate content. Thus, its protein, oil and carbohydrate content are increased there will be corresponding increase in energy yield by plant. It appears that gram crop is highly responsive to sulphur, phosphorus, nitrogen and seed treatment with *Rhizobium* culture for increasing dry matter yield, nutrients uptake and quality of gram seed in medium black soil when it is deficient in available N, P and S.

The results indicate that if oxalic acid industry waste is used in conjunction with inorganic fertilizers (nitrogen & phosphorus) and bio-fertilizer (*Rhizobium* inoculation) it will have highly beneficial effect on plant growth. Thus, the recycling of waste in agriculture will help in controlling environmental pollution.

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