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EFFECT OF SULPHUR DIOXIDE AND INSECTICIDE INTERACTION ON GROWTH AND SEED CHARACTERS OF *ORYZA SATIVA*.

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Effects of SO_2 and quinalphos, an organophosphorus insecticide were studied singly and in combination on growth and seed characters of *Oryza sativa* plants. SO_2 and quinalphos interfered with plant growth and development leading to reductions in their various morphological parameters. Similarly, grains obtained from treated plants showed quantitative and qualitative deterioration. The magnitude of adverse effects were maximum in SO_2 exposed plants followed by those exposed to SO_2 as well as sprayed with quinalphos and then in quinalphos sprayed plants showing an antagonistic mode of action between SO_2 and quinalphos with respect to above parameters in rice plants.

Key words: *Oryza sativa* Growth, Seed charactrers, Sulphur dioxide, Quinalphos.

Sulphur dioxide is a common air contaminant in urban and industrial environment with high concentrations occurring near thermal power plants, smelters and industrial complexes that use fossil fuels as an energy source. A thermal power plant, with daily consumption of 10,000 metric tons of coal may emit, 50-190 metric tons of SO_2 daily in the adjoining area depending upon the sulphur content of coal (Rao, 1985). Even at low concentrations (50-120 mg m^{-3}), SO_2 can interfere with the various physiological and biochemical processes of plants which may lead to growth and yield reductions even in absence of any visible foliar injury sysptoms (Heath, 1980; Last, 1982). Pesticides have made great impact in agricultural practices specially in India, where large quantities of pesticides (approximately 67,000 metric tons/yr) are used for green revolution. Combinations of pesticides and SO_2 may be important in many agricultural areas but little is known of their potential effects (Matsushima & Harada, 1965; Carney *et al.*, 1973; Hatzios-Kriton & Yang, 1983; Agrawal *et al.*, 1987 a,b). Pesticides can interact with gaseous pollutants and may modify plant responses. Carney *et al.*, (1973) studied phytotoxic interactions in plants treated with herbicide benefin and exposed to ozone and found less injury on tobacco cultivars. The effects of SO_2 and pesticide combinations may be less than the additive effects of the single pollutant (antagonistic), greater than the additive effects (Synergistic) or equal to the additive effects (additive).

The present study deals with the effects of SO_2 and Ekalux Ec 25 (a commercial formulation of organophosphorus insecticide quinalphos of M/S Sandoz India Ltd.) singly and in combination on growth and seed characters of *Oryza sativa* L. cv. Jaya Plants. Quinalphos [O,O-diethyl - 1 - O - quinoxalinyl - (2) - thionophosphate] is a contact insecticide of proven eficacy against a wide range of insect pests.

MATERIALS AND METHODS

Rice plants were raised in nursery condition and seedings when 20-day old were transplanted in 25 cm diameter pots (4 plants in 2 hills/pot) containing sandy loam soil. All plants were watered frequently to maintain soil moisture level to maximum field capacity.

At 45 day age, plants with uniform growth (about 42 leaves) were separated into five batches of 14 pots each designated as C for control, S for plants exposed to 0.5 ppm SO_2 for 1.0 hr, Q for plants sprayed with 0.0187% quinalphos solution (30 ml/pot), Q_1S for plants sprayed with 0.0187% quinalphos solution (30 ml/pot) and then exposed to 0.5 ppm SO_2 for 1 hr and Q_2S for plants exposed to 0.5 ppm SO_2 for 1 hr then sprayed with 0.0187% quinalphos solution (30 ml/pot). Each treatment was repeated at 7 days interval up to 66 days of plant age. The dose of quinalphos was much less than that recommended for usual agronomic practices. The chemical Ekalux Ec 25 has 25% quinalphos as active ingradient. SO_2 fumigation was done by the method described by Agarwal *et al.* (1987a). SO_2 concentration within the chamber was continuously monitored with the help of SO_2 Analyser (Model-319, Kimoto, Japan).

The fresh intact plant samples were analysed for root and shoot lengths and number of leaves, tillers and ears at 55, 70 and 85 days plant ages. The crop was harvested at maturity and their grains were collected.

Table 1: Morphological characters plant^{-1} of C, S, Q_1S, Q_2S and Q plant sets at diffe- nt ages of their growth (mean values ± SE) RL = Root length (cm), SL = Shoot length (cm), NOL = No. of leves, NOT = No. of tillers, NOE = o. of ears)

Plant age (days)	Characters	C	S	Q_1S	Q_2S	Q
55	RL	15.5±1.3	12.5±1.1^{a}	13.5±0.9^{a}	13.6±0.8^{a}	15.0±1.1^{a}
	SL	78.5±3.2	66.5±3.2^{a}	69.1±5.2^{a}	70.2±2.2^{a}	74.2±2.1^{a}
	NOL	58.2±2.2	45.1±2.4^{b}	47.1±4.1^{a}	48.0±4.2^{a}	52.1±4.5^{a}
	NOT	14.0±1.2	10.0±0.5^{b}	11.0±0.4^{b}	10.0±0.6^{b}	12.5±1.2^{a}
	NOE	-	-	-	-	-
70	RL	18.0±1.1	14.2±0.1^{b}	14.8±0.2^{b}	15.1±0.8^{b}	17.0±2.1^{a}
	SL	100.5±6.1	82.5±0.8^{b}	85.5±0.1^{b}	86.5±0.6^{b}	93.0±2.8^{a}
	NOL	60.5±1.5	45.5±2.1^{c}	48.1±1.1^{c}	48.0±1.5^{c}	55.0±2.1^{a}
	NOT	16.0±0.9	10.5±1.0^{b}	12.5±0.8^{b}	12.1±0.6^{b}	14.0±1.2^{a}
	NOE	6.0±0.1	3.0±0.02^{d}	4.1±0.08^{d}	4.0±0.02^{d}	5.0±0.03^{b}
85	RL	20.6±0.9	16.1±0.8^{b}	15.0±1.2^{b}	15.5±0.8^{b}	18.3±0.1^{a}
	SL	108.0±6.2	87.6±0.5^{b}	94.1±1.0^{b}	95.6±0.5^{b}	100.2±2.1^{a}
	NOL	64.0±1.8	48.1±2.1^{c}	51.0±1.2^{c}	50.2±1.5^{c}	58.0±1.1^{b}
	NOT	16.0±0.11	11.0±0.3^{d}	12.5±0.5^{c}	12.0±0.5^{c}	14.0±0.7^{b}
	NOE	16.0±0.2	8.5±0.3^{d}	11.2±0.5^{c}	12.0±0.4^{c}	14.1±0.5^{b}

Level of significance: a = not significant; b = $p < 0.05$; c = $p < 0.01$; d = $p < 0.001$.

Table 2: Qualitative charcteristics of rice grains collected from C, S, Q_1S, Q_2S AND Q plant sets (mean values ± S E)

Character	C	S	Q_1S	Q_2S	Q
Wt 1000 grain (g)	23.50±0.85	14.20±0.30^{d}	18.50±0.30^{c}	18.70±0.20^{c}	21.80±0.40^{b}
Energy (Kcal g^{-1}d wt)	4.56±0.10	3.21±0.13^{c}	3.80±0.14^{b}	3.85±0.16^{b}	4.00±0.13^{b}
Sulphur mg g^{-1}	3.80±0.12	4.25±0.01^{c}	4.15±0.03^{b}	4.18±0.02^{b}	3.81±0.11^{a}
Starch mg g^{-1}	731.40±12.0	656.40±10.0^{b}	689.00±9.00^{b}	695.00±5.60^{b}	715.00±12.0^{a}
Total solubla sugar mg g^{-1}	12.00±0.30	13.20±0.12^{c}	12.50±0.11^{b}	12.70±0.15^{b}	11.90±0.22^{a}
Reducing sugar mg g^{-1}	1.10±0.05	1.50±0.02^{b}	1.30±0.01^{b}	1.32±0.02^{b}	1.10±0.01^{a}
Protein mg g^{-1}	200.0±0.90	162.00±1.5[illegible]	176.00±2.50^{d}	178.00±1.80^{d}	195.50±2.80^{a}
Nitrogen %	1.77±0.03	1.45±0.01^{d}	1.58±0.02^{c}	1.59±0.02^{c}	1.69±0.02^{a}
Phosphorus mg g^{-1}	4.30±0.09	3.90±0.05^{b}	4.80±0.04^{b}	4.05±0.04^{b}	4.21±0.02^{a}
Calcium mg g^{-1}	0.70±0.02	0.50±0.01^{c}	0.57±0.02^{c}	0.58±0.01^{c}	0.62±0.01^{b}
Potassium mg g^{-1}	5.40±0.80	2.92±0.12^{b}	3.13±0.10^{a}	3.15±0.11^{a}	3.20±0.08^{a}

Level of significance: a = Not Significant b = $p < 0.05$;

c = $p < 0.01$; d = $p < 0.001$.

Weight of 1000 grains was determined. For determination of energy, minerals, (S, N, P, K & Ca) and metabolites (starch, protein, and sugars), seeds were dried in a hot oven at 80°C for 24 hr and then powdered. Energy content (k cal g^{-1} dry wt) was determined by the method of Leith (1986). The N content in grain samples was determined using micro-Kjeldahl technique (Piper, 1966). For P, S, K and Ca, the grian samples were digested in a muffle furnace at 480°C and then cooled. Ten ml of 1.0 N HCl was added, and the mixture was filtered and final volume was made up to 100 ml with distilled water. The S content (mg g^{-1} dry wt) was determined by the turbidimetric method of Rossum and Villarruz (1961). The P content was determined by the method of Jackson (1958). Ca^{2+} and K^{+} were determined in digested material using flame photometer, Perkin-Elmer, type-121 (Jackson, 1958). Total soluble sugars and reducing sugars were determined by methods of Dubios *et al.* (1956) and Somogyi (1952) respectively. Determinations of starch and portein contents were done by using the methods of McCready *et al.* (1950) and Lowry *et al.* (1951) respectively.

An average value of five replicates was taken for each of these parameters. Data were analysed using students 't' test for significance.

RESULTS AND DISCUSSION

Rice plants treated with SO_2 and quinalphos singly and in combination showed unfavourable changes in growth and development as compared to control (Table 1). Lengths of root and shoot and numbers of tillers, leaves and ears reduced with maximum reduction in SO_2 fumigated plants followed by Q_1S and Q_2S and then in Q plant sets. Plant height did not decrease significantly in Q plant set at any age but number of leaves, tillers and ears reduced significantly ($P > 0.05$) at 85 days plant age. In other plant sets, these reductions were not significant during first sampling (55-day) but later became significant with more pollutant stress. It is suggested that SO_2 interferes with various physiological and biochemical processes leading to a decrease in photosynthate production and dry matter accumulation (Last, 1982; Black, 1982). The photosymthetic leaves were affected maximally in S, Q_1S and Q_2S plant sets causing reduction in food synthesis and eventually in dry matter accumulation of root, shoot, tillers and ears. Decrease in growth of under ground parts and ears of treated plants may be consequent to decrease in growth of above ground parts, because when shoot synthesized food became too deficient to maintain the normal growth rate, sinks such as roots and reproductaive parts are more severely affected than the foliage due to reduced translocation of metabolites.

The weight per 1000 grains and energy content of grains obtained from S, Q_1S, Q_2S, and Q plant sets reduced significantly by 39.5 & 29.6, 21.3 & 16.6, 20.4 & 13.4 and 7.2 & 12.3%, respectively (Table2). The quality of grains obtained from treated plant sets was inferior to those obtained from control which suggests impairment of grain setting during pollution stress. Sulphur content in grains of S, Q_1S and Q_2S plants increased by 11.8, 9.2 and 10.0%, respectively. In contrast N, P, K and Ca contents decreased in gains as compared to control (Table 2). The amounts of soluble and reducing sugars were significantly higher in S, Q_1S and Q_2S plants but protein and starch contents of grains obtained from S, Q_1S and Q_2S plant sets were lower than those of the control. These two changes may be related and indicate either an inhibition in starch synthesis from hexose or a stimulation of starch hydrolysis (Koziol & Jordan, 1978). Changes in protein and starch turnover in treated plants grain are likely a reflection of biochemical differentiation during development of treated plants under SO_2 and quinalphos stress. Further, the decreases in metabolites and minerals of treated plant sets support the view of impared or reduced translocation of these essential constituents to developing ears.

It is well known that SO_2 decreases the rate of photosynthesis and increase respiration rate (Hallgren, 1978). Possibly, these unfavourable changes in plants are responsible for higher levels of sugars and conisquent lower values for evergy.

The data on various parameters suggest that maximum unfavourable changes were observed for SO_2 fumigated plants followed by Q_1S and Q_2S and minimum in Q plant sets. Significant increases in growth performance and yield and quality of seeds produced by Q_1S and Q_2S plants as compared to S plants suggest that quinalphos reduces the sensitivity of plants to SO_2. There was no significant difference between the effects of pre- and post-quinalphos spray application with SO_2 fumigation which further suggested that mode of such protection is mainly biochemical and not through stomatal regulation.

SO_2 after entering through stomata gets dissoved in water of intercellular spaces and of mesophyll cell walls to form sulphurous acid which later dissociates into H^+ and HSO_3^- or SO_3^{2-} ions. Sulphite and bisulphite ions oxidise to sulphate involving free radical reactions (Asada & Kiso, 1973). Possibly, quinalphos forms conjugates with these active sulphur species which may restrict excess free radical generation and subsequent changes in various physiological and biochemical processes. The higher values for sulphur content in SO_2 exposed seeds as compared to Q_1S and Q_2S seeds further support an antagonistic mode of action between quinalphos and SO_2 in rice plants.

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