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The Influence of Soil Moisture Stress on the Nutrient Uptake of *Ragi*

by

*C. K. RAJAGOPAL

Introduction: The controversy regarding the uniform availability of soil moisture within the 'available range' can be said to be set at rest following the innumerable experimental results disproving it (Kelly, 1954). In this paper the effects of differing moisture stress on *ragi (Eleusine coracana)*, on the yield and nutrient uptake of the plant are discussed.

Materials and Methods: According to Kramer (1949), the only correct method of maintaining separate soil moisture regimes at which different degrees of moisture tensions are brought to bear on the plant, is by watering the soil initially to Field Capacity and then varying rhe interval between subsequent waterings to differing periods of time. At each watering the moisture content of the soil is brought to Field Capacity. The maintenance of such moisture regimes will also simulate the actual conditions which obtain in the different soil climatic zones of varying rainfall, during a crop season.

Ten kg of a calcareous sandy loam soil from Coimbatore was employed using glazed pots. *Ragi* CO 2 was the test plant. From Field Capacity and Wilting Point, available moisture was computed. Moisture Equivalent was considered as synonymous with Field Capacity in the case of the soil used.

Initially the minimum moisture content maintained in the various regimes were 25%, 50%, 75% and 100% of Field Capacity and moisture was adjusted to Field Capacity when the minimum moisture fixed was reached by addition of distilled water. However, maintenance of 100% Field Capacity was found to interfere with soil aeration. Therefore, for the studies made beyond the seedling stage, the minimum moisture contents to which the soil in the pots was allowed to reach were modified as 25%, 40%, 60% and 80% of Field Capacity. The quantity of moisture in the pots were determined by weighing the pots.

In all the cases mentioned above the experiment was repeated with the same soil after admixture of farm yard manure at the rate of 5 tons/ha, for finding out any possible interactions between the manure and the moisture regimes.

For study at seedlings stage, *ragi* (CO 2) was sown in pots at the rate of 400 seeds per pot and the seedlings which emerged were thinned to exactly 200 per pot.

*Agricultural Chemist, Aduthurai, Tamil Nadu.

In the experiment for studying the effect of soil moisture regimes at the flowering stage, six seedlings were transplanted in each pot. The number of plants grown in the pots from which the plants were harvested at full maturity stage, was four. All the experiments were conducted as per randomised plot design. The chemical and mechanical analysis were carried out as given by Piper (1950). Estimation of protein nitrogen was done by the method described by Fujiwara and Ohira (1951).

Wilting point was determined as per the method of Veihmeyer and Hendrickson (1949).

Results and Discussion: The soil used for the experiments had the following mechanical composition, chemical constituents and physical constants.

TABLE 1. *Chemical and mechanical composition of the soil*

	%		%
Clay	24.10	Fe_2O_3	2.54
Silt	3.77	Al_2O_3	4.60
Coarse sand	54.79	CaO	1.51
Fine sand	12.76	MgO	0.43
Acid solubles	4.58	K_2O	0.42
Field Capacity	20.47	Na_2O	0.27
Wilting Point	4.53	Total N	0.032
Loss on ignitior	5.46	P_2O_5	0.061
	pH 8.30		

The data regarding analysis of plant material and grain after harvesting at the three different growth stages are given below:

TABLE 2. *Dry weight, P_2O_5, and K_2O in Ragi seedlings grown under different soil moisture regimes* (mean of 4 replications)

Moisture regime	Dry weight (g)			P_2O_5 %			K_2O %		
	Without manure	With manure	Mean	Without manure	With manure	Mean	Without manure	With manure	Mean
1	4.15	3.72	3.94	0.667	0.597	0.632	3.240	3.230	3.235
2	7.19	6.94	7.06	0.642	0.667	0.654	3.340	3.160	3.250
3	7.78	8.98	8.38	0.677	0.840	0.758	3.280	3.290	3.285
4	5.47	5.64	5.56	0.665	0.780	0.722	3.520	2.460	3.490
Mean	6.15	6.32	—	0.663	0.719	—	3.100	3.040	—

Statistical conclusion of data:

Source	Dry weight	P_2O_5	K_2O
1 Between Moisture levels	C.D.=0.690**	C.D.=0.067**	C.D.=0.180**
2 Manure *vs* No manure	N.S	C.D.=0.046**	N.S
3 Moisture level×Manure *vs* No manure	C.D.=0.071*	C.D.=0.092*	C.D.=0.250*

*Significant at 5% level **Significant at 1% level Not Significant: N.S

TABLE 3. *Dry weight, P_2O_5, and K_2O in Ragi plants grown under different soil moisture regimes and harvested at flowering stage* (mean of 4 replications)

Moisture regime	Dry weight (g)			P_2O_5 %			K_2O %		
	Without manure	With manure	Mean	Without manure	With manure	Mean	Without manure	With manure	Mean
1	4.98	6.96	5.97	0.470	0.570	0.520	4.060	4.450	4.250
2	8.51	9.86	9.19	0.530	0.630	0.580	4.320	4.500	4.410
3	10.92	11.89	11.42	0.590	0.540	0.615	4.570	4.570	4.570
4	12.61	16.25	14.43	0.640	0.800	0.720	4.910	4.890	4.900
Mean	9.36	11.24	—	0.560	0.660	—	4.450	4.600	—

Statistical conclusion of data:

Source	Dry weight	P_2O_5	K_2O
1 Between Moisture levels	C.D.=3.36**	C.D.=0.074**	C.D.=0.261**
2 Manure *vs* No manure	C.D.=1.88*	C.D.=0.051*	C.D.=0.189**
3 Moisture level×Manure *vs* No manure	N.S	N.S	C.D.=0.346**

*Significant at 5% level **Significant at 1% level Not Significant: N.S

TABLE 4. *Dry weight of Ragi plants and grain subjected to different soil moisture regimes* (mean of 4 replications)

Moisture regime	Dry weight of plants with grain (g)			Dry weight of grain (g)		
	Without manure	With manure	Mean	Without manure	With manure	Mean
1	23.36	20.90	22.13	14.23	13.31	13.77
2	35.75	38.75	37.25	18.56	18.93	18.64
3	37.43	44.85	41.14	18.93	19.95	19.44
4	44.47	46.71	45.59	20.71	21.78	21.25
Mean	35.35	37.80	—	18.11	18.45	—

Statistical conclusion of data :

Source	Dry weight of plants with grains	Dry weight of grain
1 Between Moisture levels	C.D. = 4.73**	C.D. = 1.13**
2 Manure *vs* No manure	N.S	N.S
3 Moisture level × Manures *vs* No manure	N.S	N.S

**Significant at 1% level Not Significant : N. S

TABLE 5. *P_2O_5 and K_2O in Ragi plants (after removal of grains grown under different soil moisture regimes* (mean of 4 replications)

Moisture regime	P_2O_5 %			K_2O %		
	Without manure	With manure	Mean	Without manure	With manure	Mean
1	0.445	0.845	0.605	2.440	2.940	2.690
2	0.542	0.840	0.691	3.090	3.270	3.186
3	0.603	0.903	0.752	3.280	3.300	3.290
4	0.615	0.940	0.777	3.510	3.100	3.310
Mean	0.550	0.880	—	3.080	3.150	—

Statistical conclusion of data :

Source	P_2O_5 %	K_2O %
1 Between Moisture levels	C.D. = 0.126**	C.D. = 0.215**
2 Manure *vs* No manure	C.D. = 0.089**	N.S
3 Moisture level × Manure *vs* No manure	C.D. = 0.044*	N.S

*Significant at 5% level **Significant at 1% level Not Significant : N. S

TABLE 6. *P_2O_5 and K_2O in Ragi grain obtained from plants grown under different soil moisture regimes* (mean of 4 replications)

Moisture regime	P_2O_5 %			K_2O %		
	Without manure	With manure	Mean	Without manure	With manure	Mean
1	0.707	0.805	0.756	2.820	3.116	2.960
2	0.772	0.885	0.828	2.880	4.100	3.490
3	0.802	0.915	0.858	3.640	4.620	4.130
4	0.822	0.940	0.881	4.600	4.840	4.720
Mean	0.776	0.886	—	3.490	4.160	—

Statistical conclusion of data:

Source	P_2O_5 %	K_2O %
1 Between Moisture levels	C.D. = 0.034**	C.D. = 0.261**
2 Manure *vs* No manure	C.D. = 0.027**	C.D. = 0.184**
3 Moisture level × Manure *vs* No manure	N.S	C.D. = 0.369**

*Significant at 5% level **Significant at 1% level Not Significant : N.S

TABLE 7. *Percentage of total N and ratio of Protein N to Total N in plants grown nnder different soil moisture regime at three stages of growth and in the grain obtained from the plants* (mean of 4 replications)

Stage of growth at harvest	Moisture regime	Total N %			Ratio of protein N to total N		
		Without manure	With manure	Mean	Without manure	With manure	Mean
Seedling	1	2.340	2.120	2.23	0.578	0.575	0.577
	2	1.360	1.380	1.37	0.622	0.625	0.624
	3	1.190	1.350	1.27	0.628	0.695	0.663
	4	1.130	1.260	1.95	0.790	0.735	0.762
	Mean	3.100	3.040	—	0.655	0.658	—
Flowering stage	1	3.090	2.290	2.690	0.490	0.560	0.530
	2	1.470	1.580	1.520	0.810	0.590	0.700
	3	1.300	1.090	1.200	0.870	0.680	0.770
	4	1.010	1.200	1.110	0.950	0.760	0.860
	Mean	1.720	1.600	—	0.780	0.650	—
Mature plant (after removal of grain)	1	1.408	1.082	1.245	0.710	0.582	0.646
	2	0.708	0.992	0.848	0.730	0.625	0.677
	3	0.595	0.712	0.654	0.780	0.765	0.772
	4	0.552	0.630	0.591	0.750	0.720	0.735
	Mean	0.813	0.854	—	0.740	0.673	—
Ragi grain	1	1.870	1.340	1.605	0.840	0.820	0.830
	2	1.310	1.300	1.305	0.910	0.910	0.910
	3	1.130	1.035	1.082	0.980	0.980	0.980
	4	1.130	1.050	1.090	0.990	0.990	0.990
	Mean	1.360	1.181	—	0.930	0.920	—

Statistical conclusion of data:

	Between moisture levels	Manure *vs* no manure	Moisture level × manure *vs* no manure
Seedings:			
Total N	C.D. = 0.162**	N.S	C.D. = 0.170*
Ratio of protein N to total N	C.D. = 0.052**	N.S	C.D. = 0.058*
Flowering stage:			
Total N	C.D. = 0.258**	N S	N.S
Ratio of pretein N to total N	C.D. = 0.096**	C.D. = 0.068**	C.D. = 0.136**
Mature plant (after removal of grain)			
Total N	C.D. = 0.102**	N.S	C.D. = 0.144**
Ratio of protein N to total N	N.S	N.S	N.S
Grain:			
Total N	C.D. = 0.079**	C.D. = 0.056**	C.D. = 0.112**
Ratio of protein N to total N	C.D. = 0.026**	N.S	N.S

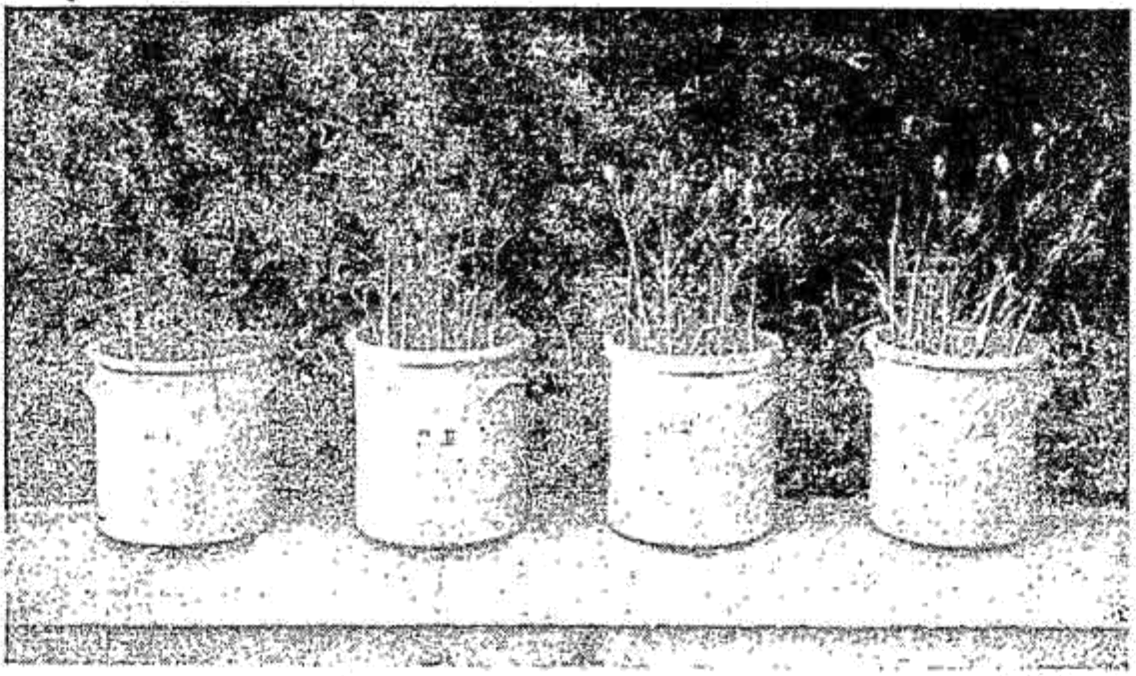
*Significant at 5% level **Significant at 1% level Not Significant: N.S

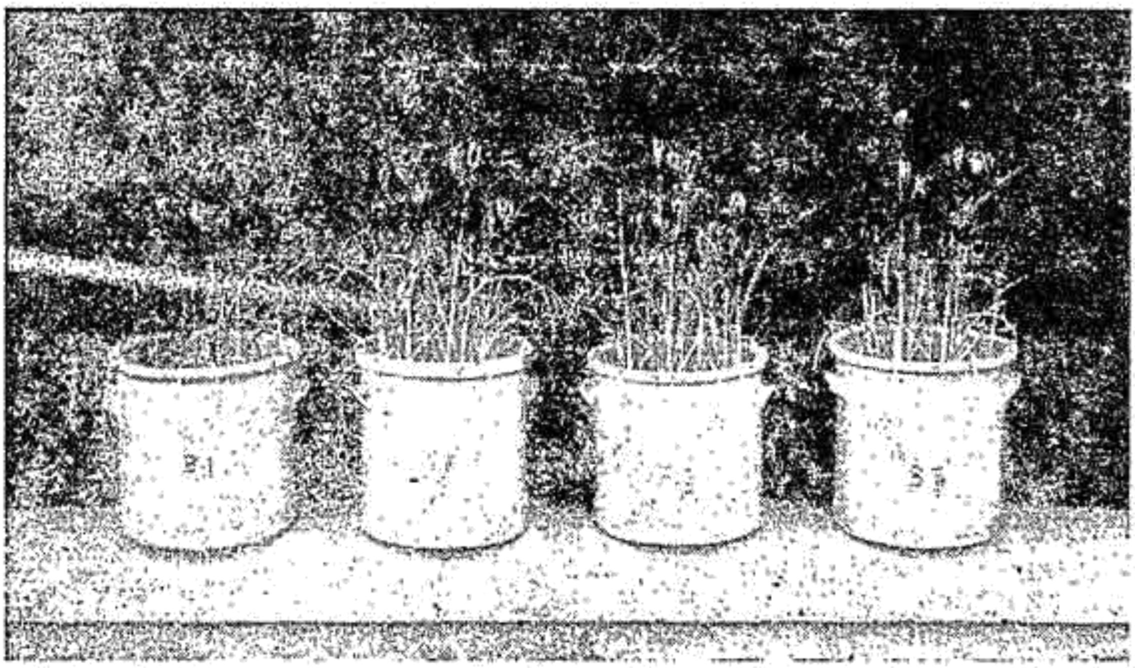
The soil moisture tension affects plant growth and yield is well known. Even relatively average soil moisture stress produces measurable reduction in growth (Beckett and Dunshee, 1932, Adams and Veihmeyer, 1942, Ayers *et al.* 1943, Cykler, 1946, Kelly, 1954, Khudairi *et al.* 1962, Connel *et al.* 1963). Although the concept of equal availability of soil moisture within the 'available range' found favour in the early years of this century, subsequent investigations have definitely proved that soil moisture becomes less available as the water content in the soil decreases rather than remaining available till the water content falls almost to wilting point (Kelly, 1954; Kramer, 1963).

The effect of soil moisture stress that becomes conspicuous from the very beginning is the restricted growth of plants. The dry matter contents of *ragi* plants grown at differing moisture regimes and harvest stages obtained in these investigations reveal that soil moisture stress affects dry matter production and restricts grain yields.

The addition of farm yard manure at 5 tons / ha does not increase dry matter produced by the plants (except at the flowering stage) nor the grain yield. The significant interaction between moisture and manure evident at the seedling stage is absent at other stages. Lessened moisture stress on the *ragi* plant favours greater absorption of P. This picture is also reflected in the grain. The increased absorption of P with increased soil moisture availability has been reported by Greaves and Carter (1923), Beeson (1941), Wadleigh and Richards (1951), Watanabe *et al* (1960) and Borchmann (1963).

According to Watanabe *et al* (1960) and Wesely (1965), the thickness of moisture film round the soil particle controls the absorption of P by plants, the thinner the film the greater the difficulty to absorb P experienced by the roots.





Ragi plants grown at different Soil Moisture Regimes (flowering stage).
Available Soil Moisture increases in the order I to IV.
Top figure is of unmanured and the bottom of manured plants.

Decreased content of P in plants growing in dry areas has been reported by Le Clerc (1907), Kunze (1914), Richardson *et al* (1931), Daniel and Harper (1935), Bourget and Carson (1962) and Finn and Black (1964). According to Emmert (1936), the lessened absorption of P by plants growing in dry soil resulted in nitrate accumulation in the tissues due to retarded tissue formation, a fact observed during these investigations also. Vilgoen (1918) and McIntosh (1934) found that the decreased content of P in cattle fodder obtained from dry areas when fed to cattle resulted in a cattle disease caused by deficiency of P.

The uptake of P from the manured soil is significantly greater, both in the plant at different growth-stages as also in the grain, proving thereby the greater absorption and translocation of P by plants growing in the manured soil.

The plants subjected to lessened moisture stress contained greater amount of K. This is highly evident in the plants at flowering stage and at full maturity. Interactions between soil moisture regime and manure are also evident at the flowering stage. The grain from plants under lessened moisture stress contains significantly higher amounts of K. The effect of manure and the interaction between manure and soil moisture regime in increasing the K content of grain is also highly significant.

That wetting and drying is conducive to fixation of K in soil has been demonstrated by Volk (1934). He also found that very little fixation took place when soils were kept continuously moist. Calcareous soils fix K even in moist condition and the fixation increases on drying as observed by Wadleigh and Richards (1951). They attribute the cause of reduction in the content of K in plants subjected to moisture stress to the fact that the rate of entry of K into the plant decreases to a greater degree than the rate of dry matter production and utilization of K in the plant (unlike N which exhibits the opposite relationship).

The uptake of N by the ragi plants is particularly high at the lower soil moisture regimes at all the stages studied. The content of total N in the grain also follows this pattern. Manuring does not affect the total N in the plants but influences that in the grain, N in the manured series being consistently less. Interaction of manure with soil moisture levels happens at the seedling stage and in the case of mature plants at harvest. In general, both in the seedlings and the mature plants, the content of total N in the manured series is higher than in the unmanured, except at the soil moisture regime of greatest stress, where it is just the reverse. Manuring does not affect the content of N in the plants at the flowering stage.

Significant interaction exists between manure and moisture at the regimes of highest moisture stress. Manuring the soil prevented undue accumulation of N in the grain in spite of heavy moisture stress.

That the larger quantities of N absorbed by the plants are not fully utilised and incorporated into the tissues is borne out from the values of the ratio of protein to the total N of the plants and grain. At the seedling and flowering stages the ratio increased with decreasing soil moisture stress. The same trend exists in the grain but is absent in the mature plant.

Manuring decreases significantly the ratio at the flowering stage. It does not affect the ratio at other growth stages or in the grain. It is suggested that the plants subjected to differing soil moisture regimes influenced not only the absorption of N but also the conversion of N into protein as well as the translocation of N from the plant to the grain. The translocation involves several reactions relating to protein hydrolysis and therefore the ratio of protein N to total N in the mature plant will be influenced by factors favouring proteolysis and catabolistic reactions in the plant. At this stage of active translocation, lessened moisture stress may even aid increase in proteolysis for effective translocation. The impossibility of maintaining any definite ratio between protein N and total N in the mature plant can thus be explained.

Extensive evidence for the accumulation of N in plants undergoing moisture stress is available (Miller and Duly, 1925, Emmert, 1936, Reitemeier, 1946, Wadleigh and Richards, 1951, Berko, 1963 and Bennet *et al* 1964). According to Wadleigh and Richards (1951) the increased N content of the plants under moisture stress is due to the steady maintenance of the rate of entry of N into the plant, irrespective of the moisture stress experienced by it, thereby leading to accumulation of N. As the growth of the plant and dry matter accumulation decreases, the percentage of N in the plant gets increased. The effect of soil moisture on N absorption is just the opposite of that produced on K absorption and the characteristics of ion entry into the plant as described by Wadleigh and Richards (1951) seems to be an apt explanation for this difference in behaviour. According to this approach nitrates and other negatively adsorbed mono-valent ions must tend to accumulate and cations and poly-valent anions must tend to decrease in plants growing under drier soil moisture conditions.

The efficiency of the plant at lower moisture levels (of less than 50% available moisture) to utilise N absorbed is less compared to other levels of soil moisture. This is evident from these investigations. This is also supported by the findings of Berko (1963) who reported that irrigation decreased the Total N content of maize root sap while increasing the Protein content.

Summary and Conclusions: The effect of moisture stress on the growth and yield of *ragi (Eleusine coracana)* within the 'available moisture range' was studied in a sandy loam soil in pots. Different soil moisture ranges were maintained by allowing the soil at Field Capacity to dry out to different moisture constants within the 'Available range'. A similar experiment with the soil manured at the rate of 5 tons of farm yard manure per acre, was also conducted. Plants were harvested at seedling, flowering and full maturity stages and the uptake of nutrients studied by analysis of whole plant material and grain. The study revealed the following :

1. The dry matter content, P and K significantly increased in the plant and grain as the soil moisture stress decreased.

2. Manuring significantly increased the P content in plants at all stages of growth and also in the grain. It also increased K in the grain.

3. Positive and significant interactions took place between moisture regimes and manure in the accumulation of dry matter, P and K at the seedling stage, K at the flowering stage and P and K in the grain.

4. Total N significantly decreased with decreased soil moisture stress at all stages of plant growth and also in the grain. Manuring did not influence the accumulation of N in plants. It decreased N in the grain. The interaction between soil moisture and manure decreased N accumulation significantly at the seedling stage and in the mature plant. This happened in the grain also.

5. Ratio of protein N to total N increased with decreased soil moisture stress and was highly significant at the seedling and flowering stages and in the grain. Manuring increased the ratio at flowering stage significantly. Positive significant interaction between soil moisture and manure was observed at seedling and flowering stages.

6. The yield of *ragi* grain from plants grown under moisture regimes of less than 50% available moisture, was less and its quality poor as judged from the content of P and K and compared to those obtained from plants grown in more moist soil. In the grain of plants undergoing high moisture stress, protein was high.

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Protection of Seeds of *Sorghum* from Infestation by the Weevil, *Sitophilus oryzae* Linn.

by

N. V. RADHA[1], C. RAMAKRISHNAN[2], R. SIVAGAMI[3] and T. GOVINDARAJAN[4]

Introduction: Among the various insects that infest *cholam* seeds, the weevil, *Sitophilus oryzae* L., is considered to be the most important one. Both the grubs and adults bore into the grains reducing them to fragments and dust. To find out an effective insecticide for the control of the pest in storage, experiments were conducted and the results are presented.

Materials and Methods: Four trials were conducted in the Entomology Section, Agricultural College and Research Institute, Coimbatore during the years 1961–62 and 1963–64 to 1965–66, by using CO 18, CO 1, CO 20 and CO 19 varieties of *cholam* seeds respectively. The seeds were kept in cloth bags at 500 g in each bag. The insecticidal treatments were dusts of Aldrin 5%, Dieldrin 1.5%, DDT 10% and Toxaphene 10% in the first two trials and Carbaryl (Sevin) 10%, Malathion 4%, DDT 10% and Toxaphene 10% in the third and fourth trials. The variants were replicated thrice. The seeds were mixed with the insecticides at the rate of 100 : 1 by weight and compared with a suitable control (without insecticides). Twenty live weevils, *Sitophilus oryzae* L. were introduced into each lot at the beginning of the trial and

1 & 4. Assistants in Entomology and 2 & 3. Assistant Entomologists, Agricultural College and Research Institute, Coimbatore-3.