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Micronutrient status in soybean (*Glycine max*) - wheat (*Triticum aestivum*) cropping system in Kumaon region of Uttaranchal

B N GHOSH¹, VED PRAKAS² and R D SINGH³

Vivekananda Parbatiya Krishi Anusandhan Sansthan, Almora, Uttaranchal 263 601

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ABSTRACT

A study was conducted during 1993-99 to assess the yield response to farmyard manure application and its fate on build up/depletion in soil and uptake of Fe, Mn, Zn and Cu in soybean [*Glycine max* (L.) Merr.]-wheat (*Triticum aestivum* L. emend. Fiori and Paol.) rotation in a long-term field experiments. Yield response curve showed sharp increase in response to farmyard manure application in soybean and succeeding wheat crop. Change in micronutrient showed that zinc levels were below the critical level in NPK treatment (< 0.6 ppm) which is alarming in intensive agriculture. Iron content increased in NPK treatment due to increase in soil acidity. Farmyard manure decreased the Fe and Mn content but increased the Zn content and maintained the Cu level in the soil. Micronutrients content in soybean and wheat were found to be present above the critical limits in all the treatments except Zn in NPK treatment and contents were significantly higher in treatments receiving farmyard manure after 26 years of cropping.

Key words: micronutrient content, uptake, farmyard manure, yield response

In Kumaon region of Uttaranchal hills, soybean (*Glycine max* (L.) Merr.]-wheat (*Triticum aestivum* L. emend Fiori & Paol.) is an important cropping sequence in rainfed farming with the application of farmyard manure to soybean crop. Greater attention is needed regarding the rate of removal of different micronutrients under this cropping pattern as the micronutrient specially zinc is below the critical level (<0.6 ppm) and deficiencies are observed in patches in valley areas (Ghosh and Singh 2000). The specific objective of this presentation is to study the yield response to farmyard manure application and build up/depletion of micronutrients in soil and uptake in crops.

MATERIALS AND METHODS

The long-term fertility experiment on soybean-wheat rotation was initiated in 1973 at Hawalbagh experimental farm located at 29°36' N latitude and 79°40' E longitude with an altitude of 1 250 m above mean sea-level and represents typical mid-hill conditions of north-west Himalayas. The treatments being followed continuously since 1973 are as given below.

T₁, (Control); T₂, N₂₀P_{35.2}K_{33.2}; T₃, N₂₀ + farmyard manure 10 tonnes/ha; T₄, N₂₀P_{35.2}K_{33.2} + farmyard manure 10 tonnes/ha.

These treatments were applied to 'Bragg' soybean crop only while 'VL 421' wheat was grown on residual fertility. The

duration of soybean was June to September while that of wheat second fortnight of October to end of April. Both the crops were grown under rainfed conditions. On an average, soybean and wheat received 831.5 and 196.1 mm seasonal rainfall during the growing period respectively. Nitrogen, phosphorus and potassium were applied through urea, single super phosphate and potassium chloride respectively, whereas farmyard manure was applied @ 10 tonnes/ha. The experiment was laid out in randomized block design with six replications on a Typic Haplaquept. The soil was sandy loam and a pH 5.7, organic carbon 0.52 %, Clay- 5.8%, CEC - 8.7 C mol (p+)/ha/kg, available N, P and K were 239, 16.8 and 106.6 kg/ha, respectively. Chemical composition of farmyard manure were 13.34% C, 1.11% N, 0.5% P, 0.5% K, 0.91% Ca, 1.1% Na, 14.5 ppm Zn, 2.8 ppm Cu, 410 ppm Fe, 69 ppm Mn, 5.0 ppm B, 21.0 ppm Mo, and C:N ratio 12.0.

Soil samples (0-15) were collected before sowing of each crop and subsequently after the harvest of each crop. The samples were air dried and crushed to pass through a 2 mm sieve before chemical analysis. Plant samples from each crop were processed and digested in tri-acid mixture and used for the micronutrients, Fe, Mn, Zn and Cu analysis on atomic absorption spectrophotometer following the method of Lindsay and Norvell (1978). The details of the experiment was described by Ghosh *et al.* (1998). The data of last five years from 1994 to 1998-99 are presented in this communication.

¹Scientist (Soil science), ²Senior Scientist (Agronomy), ³Senior Scientist (Agricultural Chemistry)

RESULTS AND DISCUSSION

Yield response

The yield response curve of soybean due to farmyard manure application clearly indicated gradual increase in yield (R^2 values for soybean 0.3074), but increase was higher in soybean than succeeding wheat crop ($R^2 = 0.2753$) (Fig 1). The quadratic yield response curve for both the crops suggested variability in yield in different years with the variation of rainfall as the crops were grown rainfed. The average yield of soybean and wheat for the period 1973-99 also clearly indicated variation in yield among the treatments with higher coefficient of variations due to imbalance of fertilization and rainfed cropping (Table 1).

Table 1 Average yield of soybean and wheat (1973-1999) under different manurial treatments

Treatment	Soybean yield (tonnes/ha)	CV (%)	Wheat yield (tonnes/ha)	CV (%)
Control	0.54	50.26	0.52	48.23
NPK	1.45	26.31	1.04	45.97
N+Farmyard manure	2.20	22.44	1.47	40.15
NPK+Farmyard manure	2.65	15.60	1.76	30.15

Change in pH and organic carbon

Last five years average pH showed that there was a drop in pH in NPK treatment due to acid equivalent of the inorganic fertilizer (Fig 2). The soil reaction increased in farmyard manure treated plots. Organic carbon was maintained in NPK treated plots or slightly decreased due to huge biomass/leaf fall of soybean. Organic carbon has increased significantly in farmyard manure treated plot (Fig 2).

Available micronutrients

Iron: Marked increase in available Fe was noted over the years in comparison to the initial value in NPK treatment. This increase in available Fe suggests that determination of Fe with DTPA method does not provide a reliable estimate of available Fe for all kinds of soils (Fig 3). However, the very high value of available Fe in NPK treatment could be ascribed to increased acidity over the years resulting in increased solubilisation of Fe (Nambiar 1994). On the contrary, considerable reduction in available Fe was noted in farmyard manure treated soils which amounted to about 60.5 and 63% from initial value in N+farmyard manure and NPK+ farmyard manure treatment respectively.

Manganese: A marked reduction of available Mn was noted on NPK, N-FYM and NPK-farmyard manure treatment to the tune of 57, 56.4 and 55.3% respectively might be due to microbial population (bacteria and fungi) which oxidise Mn^{+2} to brown manganic forms (Mn^{+3}) in presence of neutral

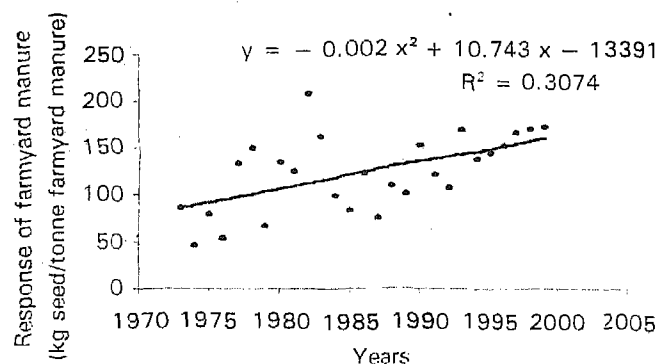


Fig 1 Response of farmyard manure application to soybean crop over the years

salts of hydroxy acids, viz citric, malic, lactic and gluconic which is produced by the microbial decomposition of root and leaves biomass of soybean.

Zinc: The available soil Zn decreased by about 37.5% in NPK treatment from the initial values over the last 26 years indicating alarming situation in this intensive crop rotation. Incorporation of farmyard manure (along with optimal NPK fertilizers) not only maintained the initial level but also improved over it.

Copper: There was no remarkable change in respect of Cu. Nevertheless, the availability of these nutrients was still quite high inspite of intensive cropping for over 26 years and did not indicate any adverse effects on crop production. This might be ascribed as the pH values of soil solution was below 6.9, the divalent ion Cu^{+2} is the dominant form of this element its solubility in the soil solution decreases 100- fold for each unit increase in soil pH besides soil texture, organic matter and interaction with other micronutrients.

Uptake

Iron: Iron uptake improved appreciably in treatments which received farmyard manure and uptake was more in soybean crops than wheat (Fig 4).

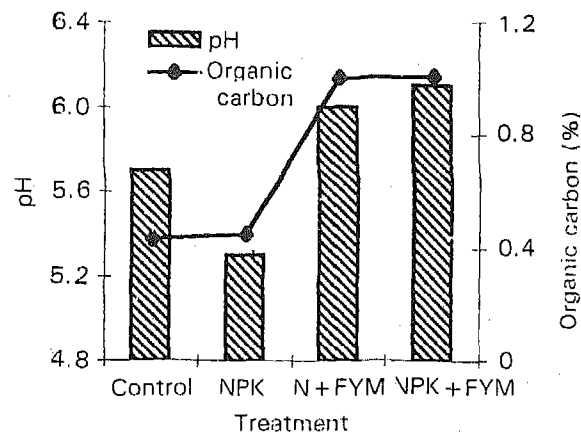


Fig 2 Changes in pH and organic carbon over the years

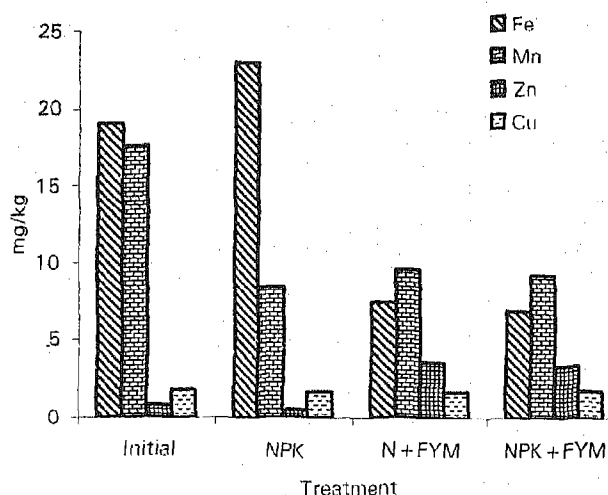


Fig 3 Available micronutrients after harvest of wheat (average of 5 years)

Manganese: The highest Mn uptake was noted with the combined application of NPK fertilizers and farmyard manure (Fig 4). Mn uptake with NPK+farmyard manure treatment was 2 folds more in case of soybean than wheat. Increase in uptake of micronutrients with increase in fertility level was also reported by Sakal *et al.* (1993). The difference in uptake of Mn between soybean and wheat varies greatly because of their genetic make up (more root CEC of the soybean crop) which yielded higher bio mass production (Gupta and Mehla 1993).

Zinc: The uptake of Zn was also increased with the balanced application of NPK fertilizers though Zn content in soil has dropped in this treatment due to increased acidity. There is further increase in uptake when NPK was applied along with farmyard manure. Calculation of expected years to last (Table 2) indicates that Zn will be exhausted earlier further supporting the alarming situation in this crop rotation.

Copper: The uptake of Cu generally improved with the balanced application of NPK fertilizers which showed further improvement with NPK + farmyard manure treatment. The average figures for Cu uptake with N+ farmyard manure and NPK+ farmyard manure treatments were 118, 138 g/ha for soybean and 62, 86 g/ha for wheat, respectively.

Table 2 Micronutrients content in soil, crop removal and expected numbers of years* expected to elapse before they are exhausted

Micronutrient	Mean (mg/kg)	Mean (kg/ha)	No. of years to last
Fe	19.0	41.8	53.0
Mn	17.5	38.5	69.5
Zn	0.8	1.76	20.5
Cu	1.7	3.74	79.6

* It is assumed that the soil reserve of micronutrients would supply continuously as required by the crop rotation

The biomass produced by soybean was higher than wheat as well as the average uptake of Fe, Mn, Zn and Cu by a single crop of soybean is higher than that of wheat. The crops also differ significantly in their requirements to remove micronutrients from the soil as also reported by Nambiar (1994). The uptake of Fe and Mn is much higher than that of Zn and Cu because of their initial higher concentration in these soils.

Thus, it could be seen that the uptake by crops was by and large the highest with the combined application of chemical NPK fertilizers and farmyard manure. However, zinc levels in soils were just below the critical levels which is supported by expected number of years expected to elapse before they are exhausted after two and half decades of intensive farming. It was found to be associated with the emergence of deficiencies of one or more of the plant nutrients leading to

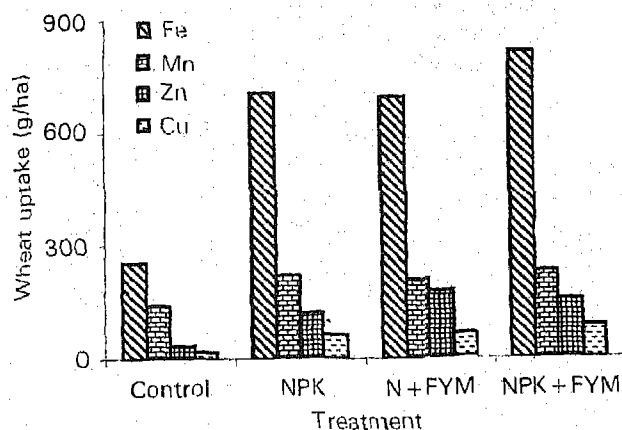
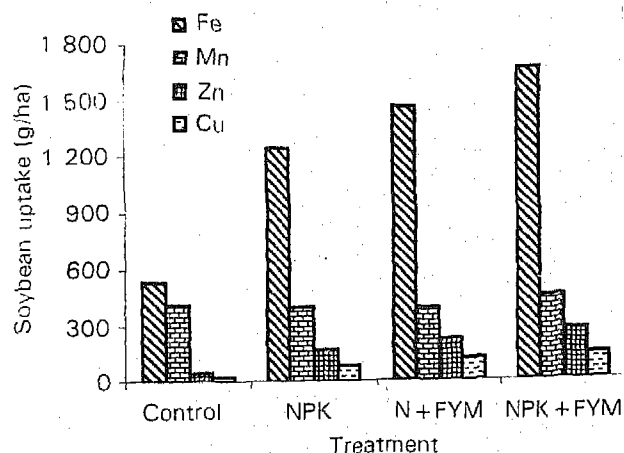


Fig 4 Uptake of micronutrients (average of 5 years)
FYM, Farmyard manure

decreased productivity. It is therefore, of paramount importance that a rigorous monitoring of major, secondary and micronutrient elements in soils may be done in order to identify nutrient stresses and to augment those nutrients which are yield limiting. It would go a long way in maintaining sustained productivity.

REFERENCES

- Ghosh B N and Singh R D. 2000. Distribution and status of micronutrient in a subtropical soils of UP hills. *International Congress on Management of Natural Resources*, pp 255-77.
- Ghosh B N, Ved Prakash and Singh R D. 1998. Yield response and nutrient use efficiency on soybean-wheat cropping system in a long-term manurial experiment. *Long-term Soil Fertility Management through IPNS*. Swarup A, Reddy D D and Prasad R N (Eds). IISS, Bhopal, pp 277-82.
- Gupta V K and Mehla D S. 1993. Depletion of micronutrients from soil and their uptake in rice-wheat rotation. *Journal Indian Society of Soil Science* **41** : 704-6.
- Lindsay W L and Norvell W A. 1978. Development of a DTPA soil test for zinc, manganese and copper. *Soil Science Society of America Journal* **42** : 421-8.
- Nambiar K K M. 1994. *Soil fertility and crop productivity under long-term fertilizer use in India*. ICAR, Krishi Anusandhan Bhavan, New Delhi.
- Sakal R, Singh A P, Singh R P and Bhagat N S. 1993. 25 years of research on micronutrient in soils and crops of Bihar. *Annual Report, All India Coordinated Scheme of Micronutrients in Soils and Plants*, RAU, Pusa, Bihar.

Effect of water stress on growth, productivity and water expense efficiency of summer rice

S SARKAR¹

Regional Research Station AICRP on Water Management, Bidhan Chandra Krishi Viswa Vidyalaya, Gayeshpur, West Bengal 741 234

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ABSTRACT

A field study was carried out during 1997 and 1998 cropping seasons on a fine loamy (Typic Ustochrept) soil type, to assess the performance of 'IET 4786' summer rice (*Oryza sativa* L.) under stressed (intermittent ponding) and non-stressed (continuous ponding) situations. In case of intermittent ponding, irrigation was given when soil-moisture tension at 20 cm depth attained the suction value of 0.02 M Pa. Entire irrigation period was divided into 3 stages, ie early [11 to 30 days after transplanting (DAT), middle (31 to 60 DAT) and late (61 to 80 DAT) stages. Intermittent ponding was imposed at single, ie in early (I_2), middle (I_3) and late (I_4) stage or at two stages, ie early plus middle (I_5), early and late (I_6) and middle plus late (I_7) stages. Besides, there were 2 more irrigation regimes, ie continuous ponding was maintained throughout the entire irrigation period (I_1) and intermittent ponding was maintained during the entire irrigation period (I_8). The highest grain yield (6.79 Mg ha) was attained under I_1 , followed by yield of 6.71 Mg ha under I_2 . Grain yield markedly decreased under I_3 , I_5 , I_7 regimes and it attained lowest value (5.37 Mg ha) under I_8 . Water expense efficiency (W_{ee}) value attained the lowest level (5.26 kg/ha/mm) under I_7 regime. While it was highest (5.99 kg/ha/mm) under I_2 regime and this W_{ee} value was 8.7% higher over I_1 . Though grain yield attained lowest value under I_8 but minimum level of water expense value (910.4 mm) responsible towards greater W_{ee} value (5.71 kg/ha/mm) under this treatment.

Key words: rice intermittent ponding, water expense efficiency

The area of summer rice under tubewell command area in West Bengal has shown gradual increase (7.46% annually) during 1981-82 to 1995-96. Better monetary return is the reason behind such an increasing trend. As the water requirement for rice is quite high during this season, huge amount of ground water is needed to meet the irrigation demand. Massive use of ground water for summer rice over the years has resulted in decrease in ground water level making it more expensive and scarce. Rice crop has specific plant development phases and characteristics when the crop water requirement is high and response pattern do change with differential irrigation regimes (Chaudhary 1997). Consideration on hydro-ecological balance and crop stage factors are the prerequisites for the development of efficient water management practices for the cultivation of summer rice crop. Under shallow water table conditions, continuous saturation or intermittent ponding during the vegetative stage does not generally affect the grain yield of rice significantly (Misra and Panda 1994). However, in Japan it has been reported that continuous ponding in the first half of the growing season and alternate drying and ponding in the later half enhance productivity of the rice crop (Watanabe

1992). Saturation up to maximum tillering followed by shallow submergence was observed to give the best yield of rice in Hirakud command area of Orissa, where the ground water table was at 20 to 30 cm depth (Das 1992). Rao and Venkateswarlu (1989) reported that moisture-stress at reproductive and ripening stage is crucial for growth and productivity of rice. Keeping these in view the present study was carried out with two aims, (i) to identify the stress allowable stage(s) of the crop and (ii) to assess how much loss due to stress at one stage can be recovered by the crop if it is exposed to non-stressed situation at later stage(s).

MATERIALS AND METHODS

Field experiments were carried out during January to May 1997 and 1998 at the experimental farm (88° 3' N, 22° 58' E and 9.75 m altitude) of the Regional Research station for new Alluvial zone of Bidhan Chandra Krishi Viswavidyalaya. The soil was a member of fine loamy (14% sand, 41% silt and 45% clay), mixed hyperthermic family of Typic Ustochrept with surface (0-0.15 m), bulk density value 1.47 Mg/m³ and percolation rate 11 mm/day. The major chemical properties of the soil were : pH 6.5, organic carbon 0.54%, available nitrogen, P₂O₅ and K₂O and 85.0, 156.5 and 153.57 kg/ha respectively. The entire irrigation

¹Reader

Table 1 Total tillers, effective tillers and plant height of summer rice at 80 days after transplanting in two cropping seasons under different irrigation regimes

Treatment	Total tillers			Effective tillers			Plant height (cm)		
	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean
I ₁	112	126	124	111	115	113	87	97	92
I ₂	105	112	108	103	107	105	82	91	86.5
I ₃	102	106	104	97	98	97	80	91	85.5
I ₄	122	126	124	101	109	105	83	92	87.5
I ₅	92	93	92	78	83	80	75	83	79
I ₆	105	112	108	89	88	88	79	88	83.5
I ₇	102	106	104	74	78	76	76	88	82
I ₈	92	93	92	73	75	74	73	84	78.5
LSD (P=0.05)									
Year (Y)			NS			NS			NS
Irrigation (I)			4.407			6.635			4.251
Y×I			6.649			9.384			6.012

period was divided into three stages : early (11-30 days after transplanting (DAT, S₁); middle (31-60 DAT, S₂) and late (61-80 DAT, S₃) states. Two type of soil water regimes were imposed, i) continuous ponding (CP) and ii) intermittent ponding (IP). In IP, irrigation was given when the soil moisture tension at 20 cm depth attained 0.02 MPa suction. Soil moisture tension was measured with the help of mercury manometric type tensiometers. Middle part of the tensiometer cup was placed at 20 cm depth. Under the check treatment (I₁) continuous ponding was maintained throughout the entire irrigation period (11-80 DAT). Intermittent ponding was imposed either in a single phase, ie in early (I₂), middle (I₃) or late (I₄) stage or in two different phases, ie in early plus middle (I₅), early and late (I₆) or middle plus late (I₇) stages. Beside these, in one treatment intermittent ponding was maintained throughout the irrigation period (I₈). These eight treatments on water regimes were tested in 5 m × 6 m plots arranged in

randomised block design with three replications. Statistical analysis was done on seasons, treatments and their interactions. 'IET 4786' rice was taken as a test crop. Depth of irrigation was 50 mm under continuous ponding and it was 0 mm for intermittent ponding condition. The depth of irrigation was as calculated by following an equation as mentioned below. The equation has been developed by Chaudhary (1997).

$$D_i = (\theta - \theta_i + D_s) \dots (1)$$

where, D_i is depth of irrigation water to be applied (mm), D_r is depth of root zone (mm), D_s is the depth of submergence required (mm), in the present study D_s value was 50 mm, θ_s is the average volumetric soil water content (m³/m³) of the root zone at saturation and θ_i is the average volumetric soil water content (m³/m³) when irrigation water is applied. Under continuous ponding number of irrigations

Table 2 Total tillers, effective tillers and plant height of summer rice at 80 days after transplanting in two cropping seasons under different irrigation regimes

Treatment	Days after transplanting								
	30			60			80		
	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean
I ₁	4.25	4.55	4.40	6.56	6.7	6.63	4.72	4.85	4.78
I ₂	3.54	3.64	3.59	5.64	5.74	5.69	4.29	4.4	4.34
I ₃	4.25	4.55	4.40	5.65	5.79	5.72	4.01	4.12	4.07
I ₄	4.25	4.55	4.40	6.56	6.70	6.63	4.46	4.57	4.51
I ₅	3.54	3.64	3.59	4.93	5.01	4.97	3.57	3.68	3.62
I ₆	3.54	3.64	3.59	5.64	5.74	5.69	3.80	3.89	3.83
I ₇	4.25	4.55	4.40	5.65	5.79	5.72	3.56	3.63	3.59
I ₈	3.54	3.64	3.59	4.93	5.01	4.97	3.35	3.40	3.37
LSD (P=0.05)									
Year (Y)			NS			NS			NS
Irrigation (I)			0.232			0.965			0.302
Y×I			0.328			1.36			0.427

Table 3 Biomass of summer rice at different crop growth stages in two cropping seasons under different irrigation regimes

Treatment	Days after transplanting [Biomass (g/m)]								
	30			60			80		
	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean
I ₁	63	68	65.5	298	358	328	509	580	544.5
I ₂	50	53	51.5	261	287	274	458	510	484
I ₃	63	68	65.5	214	254	234	404	440	422
I ₄	63	68	65.5	298	358	278	425	468	446.5
I ₅	50	53	51.5	179	198	188.5	326	434	380
I ₆	50	53	51.5	261	287	274	356	403	379.5
I ₇	63	68	65.5	214	254	234	342	386	364
I ₈	50	53	51.5	179	198	188.5	249	294	271.5
LSD ($P=0.05$)									
Year (Y)			NS			NS			NS
Irrigation (I)			5.521			18.21			NS
Y×I			7.804			25.73			NS

were 8, 7 and 5 at early, middle and late stage of irrigation period. Under intermittent ponding irrigations number were 5, 4 and 3 only. Data on amount of rainfall and potential evapotranspiration loss (PET) at each crop growing period are presented in Fig 1. In 1998 higher amount and better distribution of rainfall (Fig 1) during the cropping period decreased the irrigation demand of the crop. During 1998 because of 48.1 cm higher rainfall at early stage, two number less irrigations were given to all the treatments at that stage. Important biometric parameters were studied at 80 DAT. Crop was harvested at 95 DAT during both the cropping seasons.

RESULTS AND DISCUSSION

Tillers

In comparison to total tillers the effective tiller number decreased by 3.8 to 38.15%. It was at a moderate (9.73%) level under I₁ regime. However, when the crop was under intermittent ponding during the entire irrigation period (I₈

regime) the decrease was 20.9% (Table 1). Decrease in effective tiller number was minimum (3.8%) when intermittent ponding was imposed only at early growth stage (I₂ regime). However, intermittent ponding at S₃ stage the same reduced by 15.7%. Exposure of the crop to intermittent ponding situation during two growth stages showed minimum decrease (14.9%) when it was imposed at S₁ (11–30 days after transplanting, DAT) and S₂ (31–60 DAT) stages. However, intermittent ponding at S₂ and S₃ (61–80 DAT) stages resulted in maximum (38.15%) decrease in effective tiller numbers of the crop. Data from Table 1 revealed that, imposition of intermittent ponding at reproductive stage (S₃) had more impact on reduction in effective tiller number. Exposure to intermittent ponding either in a major part as in under, I₅ or during the entire irrigation period (I₈) responsible towards maximum disorder in different physiological process of the plant system and

Table 4 Grain and straw yield of summer rice in two cropping seasons under different irrigation regimes

Treatment	Grain yield (Mg/ha)			Straw yield (Mg/ha)		
	1997	1998	Mean	1997	1998	Mean
I ₁	6.71	6.87	6.79	6.93	7.07	7.00
I ₂	6.60	6.82	6.71	6.92	7.13	7.02
I ₃	5.83	6.05	5.94	6.26	6.39	6.32
I ₄	6.12	6.31	6.12	6.54	6.78	6.86
I ₅	5.63	5.78	5.70	6.30	6.46	6.38
I ₆	6.01	6.13	6.07	6.89	7.01	6.95
I ₇	5.55	5.63	5.59	6.48	6.53	6.50
I ₈	5.32	5.43	5.37	6.23	6.36	6.29
LSD ($P=0.05$)						
Year (Y)			NS			NS
Irrigation (I)			0.2404			0.2115
Y×I			0.3399			0.2991

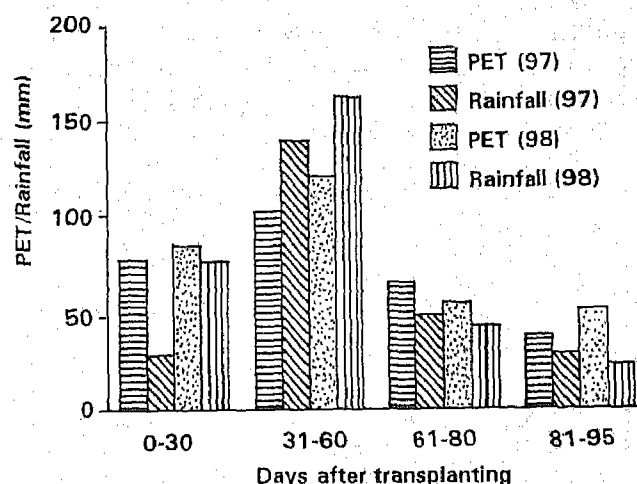


Fig 1 Potential evapotranspiration (PET, mm) and rainfall (mm) during different cropping period of summer rice during 1997 and 1998 seasons

Table 5 Total water expense and water expense efficiency (W_{ce}) of summer rice under different irrigation regimes

Treatment	Amount of water used			amount of rainfall			Total water expense			W_{ce} (kg/ha mm ⁻¹)		
	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean
I ₁	1000	900	950	251.8	310.4	281.1	1 251.8	1 210.4	1 231.1	5.36	5.67	5.51
I ₂	900	780	840	251.8	310.4	281.1	1 151.8	1 090.4	1 221.1	5.73	6.25	5.99
I ₃	890	790	840	251.8	310.4	281.1	1 141.8	1 100.4	1 121.1	5.10	5.49	5.29
I ₄	930	830	880	251.8	310.4	281.1	1 181.8	1 140.4	1 161.1	5.18	5.53	5.35
I ₅	790	670	730	251.8	310.4	281.1	1 041.8	980.4	1 011.1	5.40	5.89	5.64
I ₆	830	710	770	251.8	310.4	281.1	1 081.8	1 020.4	1 051.1	5.55	6.00	5.77
I ₇	820	720	770	251.8	310.4	281.4	1 071.8	1 030.4	1 051.1	5.17	5.35	5.26
I ₈	720	600	660	251.8	310.4	281.1	971.8	910.4	941.1	5.47	5.96	5.71

resulted in marked decrease in both total and effective tiller numbers.

Plant height

At 80 DAT highest plant height (92 cm) value was recorded under I₁ regime (Table 1), where the crop was not exposed to stress situation during the entire irrigation period. Imposition of intermittent ponding at a single stage was responsible for 5.1 to 7.6% decrease in plant height as compared to I₁ regime. As the plant height of rice used to increase even during post flowering period, water stress only at S₂ or during both S₁ stages reduced the plant height to a notable degree. When intermittent ponding was imposed during two growth stages the decrease in plant height ranged between 10.2 to 16.4%. Ponding during S₁ stage but under continuous ponding state at S₂ stage (I₂ and I₆ regimes). In contrast to this sequence, reduction in biomass was 40.1% under I₃ and I₇ regimes where the crop was exposed to continuous ponding during S₁ stage but under intermittent ponding during S₂ stage. Data from Table 3 revealed that, imposition of intermittent ponding during S₂ stage had maximum impact in reduction of biomass production of the crop. Intermittent ponding during two stages resulted in subsequent decrease (74.4) in biomass yield when it was imposed during S₁ and S₂ stages. However, when the crop experienced intermittent ponding during S₂ and S₃ stages the extent of loss of biomass was comparatively less (49.5%). At the later (80 DAT) phase of the cropping period a two fold increase in plant biomass was recorded under I₁ regime as compared to I₈.

Grain yield

Highest grain yield (6.79 Mg/ha) was recorded under continuous ponding (I₁) condition (Table 4). This was closely followed by I₂ (6.71 Mg/ha) where intermittent ponding was imposed during S₁ (11 - 30 DAT) stage. A better recovery during S₂ stage is the probable reasons for second highest yield under I₂ regime. While intermittent ponding during S₂ stage (31 to 60 DAT, I₃ regime) rice productivity decreased by 14.3% in comparison to I₁ regime. Difference in grain yield between I₁ and I₆ (intermittent

ponding at S₁ and S₃ stage) regime was 12%. Imposition of intermittent ponding during two stages resulted in 19.2 to 21.4 % decrease in grain yield respectively under I₅ and I₇ irrigation regimes as compared to I₁ irrigation regime. Lowest grain yield was recorded under I₈ irrigation regime. Substantial quantities of carbohydrates are accumulated in different parts of rice (Perez *et al.* 1971) which are of paramount importance when plant experiences water deficit at flowering (Rahaman and Yoshida 1985). Pre-anthesis assimilates stored in stem and leaf sheath tissue appear to contribute substantially to grain filling under water stressed condition (Akita 1987, Chaturvedi and Ingram 1989). Due to these reasons a moderate decrease in grain yield occurred under I₄ and I₆ regimes where the plant was exposed to intermittent ponding during S₃ stage. Specific leaf weight have influenced the photosynthetic rate of rice (Swain and Murthy 1997) and thus there will be a variation in yield with different water regimes.

Leaf area index

In the present study it was observed that intermittent ponding 11-30 days after transplanting reduced the total leaf numbers per plant as size of the leaf and due this reason LAI value decreased by 22.56% at 30 DAT under I₂ regime (Table 2). Favourable soil water regime through imposition of continuous ponding at 31-60 DAT after an intermittent ponding at 11 - 30 DAT was responsible for partial recovery in LAI values at 60 DAT under I₂ and I₆ regimes narrowed down at 60 DAT. This was because, when the crop was exposed to non-stressed (continuous ponding) situation after the stressed (intermittent ponding) one, stored assimilates enhanced the physiological recovery of plants (Wardlaw and Eckhardt 1987). Between 31 to 60 DAT, LAI under I₁ and I₄ irrigation regimes increased by 50.68% while under I₈ treatment the increase in LAI was only 38.44%. Imposition of intermittent ponding during S₂ stage (I₃ and I₇ regimes) or during both S₁ and S₂ stages (I₅ and I₈ regimes) reduced the LAI by 15.9 to 33.4 % as compared to continuous ponding (I₁). As the peak vegetative stage of the crop was under S₂ stage, maintenance of intermittent ponding only during that stage result in a notable decrease in LAI values

under I_3 regime. Continuous stress during both S_1 and S_2 stages was responsible for minimum level of carbohydrate accumulation as a result LAI values under I_3 and I_8 regimes were at lowest level. Irrespective of soil water regime leaf area index attained the highest value at 60 DAT and thereafter it decreased by 38 to 48 % at 80 DAT. Soil water stress at S_3 stage had little impact on LAI values of the crop (Table 2).

Biomass

Imposition of intermittent ponding during S_1 stage resulted in 23% decrease in plant biomass production (Table 3). Growth of the crop depends on two factors, i.e. current photosynthesis rate and stored assimilates. When current photosynthesis is limited by water stress the remobilisation of stored assimilates is accelerated and plant is forced to depend on stored assimilates (Blum *et al.* 1993). This was the reason for lower level of LAI and biomass values during S_1 stage when the crop was under intermittent ponding (I_2 regime) as compared to non-stressed (continuous ponding, I_1 regime). At 60 DAT a comparative study with I_1 regime showed a gradual (19.7%) decrease in plant biomass when the crop was under intermittent ponding.

Crop water use

Continuous ponding throughout the irrigation period resulted in maximum (950 mm) use of water for irrigation purpose to the crop field under I_1 regime (Table 5). In contrast to this, under I_8 regime where the crop experienced intermittent ponding throughout the irrigation period only 660 mm water was irrigated to the crop. In the present study water expense efficiency (W_{ee}) attained the highest value (5.99 kg/ha mm) under I_2 regime where 110 mm less irrigation water was used and grain yield was insignificantly lowered as compared to I_1 regime. Second highest value (5.77 kg/ha mm) of W_{ee} was attained under I_6 regime. In case of I_8 regime, where intermittent ponding was maintained throughout the irrigation period only 660 mm of irrigation water was used. Minimum amount of water expense responsible for the third highest W_{ee} value (5.71 kg/ha mm) under this regime. Impact of water stress condition during S_2 stage (I_3 regime) of the crop had severe effect on grain yield and thus resulted in minimum level of W_{ee} value (5.24 kg/ha mm). Though magnitude of grain yield attained the highest level (6.79 Mg/ha) under I_1 regime but more amount of irrigation water was responsible for moderate (5.51 kg/ha mm) level of W_{ee} under this regime. In comparison to 1997, 23.27% more rainfall occurred in 1998 during the entire cropping period. Due to this magnitude of total water value was 3.7 to 6.7 % lower during the second cropping season (Table 5).

So far the water-expense efficiency (W_{ee}) is concerned we have to select that irrigation regime where a little reduction in productivity occurred with a notable decrease in total water used for irrigation. In the present study, W_{ee}

value under I_2 regime thus can be marked as an optimum one because in this treatment 1.19% . A saving of 11 cm water in a single cropping season means, in Nadia district (where the cultivated area of summer rice during 1996-97 was 83.94 km²) a total of 9.24 million M³ ground water can be saved if the farmers adopted I_2 irrigation regime.

In the present study during 1998, potential evapotranspiration demand at S_1 and S_2 stages were respectively 9.73 and 17.16% higher, over that of 1997 (Fig 1). In the same tune rainfall value during 1998 were 15.66 and 15.87 % higher at those two stages. Higher ET demand and greater amount of rainfall with better distribution responsible for higher transpiration pull and photosynthesis rate during 1998 as compared to 1997 and thus resulted in higher productivity level.

Thus it can be concluded that, water stress at 31 to 60 days after transplanting is more severe so far the productivity of the crop is concerned. Water stress during early vegetative (11-30 DAT) stage can be recovered by the crop if it is exposed to non-stressed environment at later stage and imposition of intermittent ponding during early vegetative stage can save a notable amount of irrigation water without much affecting the productivity level.

REFERENCES

- Akita S. 1987. Physiological aspects for improving yield potential in tropical rice cultivation. Paper presented in International Rice Research Conference held during 21-25 September 1987 at the IRRI, Manila, Philippines.
- Blum A, Poiarkova H, Golan A and Mayer J. 1993. Chemical desiccation of wheat plants as simulator of post anthesis stress. I. Effects on translocation and kernel growth. *Field Crops Research* 6 : 149-55.
- Chaturvedi G S and Ingram K T. 1989. Growth and yield of low land rice in response to shade and drainage. *Philippines Journal of Crop Science* 14 : 61-7.
- Chaudhary T N. 1997. *Water management in rice for efficient production*. Bulletin, Directorate of Water Management Research, Patna.
- Das K C. 1992. *Proceedings of Soil and Water Engineering for Paddy Field Management*. Asian Institute of Technology, Bangkok, Thailand, pp 85-98.
- Misra C P and Panda D. 1994. Land and water management in eastern India. (in) *Management of land and water for sustainable agriculture and environment*. (Dev D L, Narayanaswami N, Sidhu P S, Sachdeva M S and Rattan R K (Ed), Special publication by Indian Society of Soil Science, pp 121-44.
- Perez C M, Pahniano E P, Baun C L and Julliano B O. 1971. Starch metabolism in leaf sheaths and culm of rice. *Plant Physiology* 47 : 404-8.
- Rahaman M S and Yoshida S. 1985. Effect of water stress on grain filling in rice. *Soil Science and Plant Nutrition* 31 : 497-511.
- Rao K S and Venkateswarlu B. 1989. Influence of moisture stress at ripening on indigenous water levels and sterility in rice. *Ametical Agricultural Research* 10 : 285-91.
- Swain P and Murthy K S. 1997. Direct and indirect effects of different leaf characteristics on photosynthetic rate in rice.

Oryza 34 : 269-71.

Wardlaw I F and Eckhardt L. 1987. Assimilate movement in lolium and sorghum leaves. IV. Photosynthetic response to reduced translocation and leaf stage. *Australian Journal of Plant*

Physiology 14 : 573-91.

Watanabe Y. 1992. *Proceedings of Soil and Water Engineering for Paddy Field Management*. Asian Institute of Technology, Bangkok, Thailand, pp 85-98.

Fodder and seed yields as influenced by row spacing and cutting management of component crops in berseem based intercropping systems

S S NARWAL¹ and VIRENDER SARDANA²

CCS Haryana Agricultural University, Hisar 125 004

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ABSTRACT

A 2-year field experiment was conducted at Hisar, during the winter season 1993-94 and 1994-95 to study the influence of component crops on the fodder and seed yield of berseem (*Trifolium alexandrinum* L.). An intercropping of berseem with *Brassica* crops in different row spacings (100, 150 and 200 cm) and cutting management (no cut, 1 cut, 2 cuts) significantly influenced the total green fodder yield. The maximum increase over sole crop of berseem was registered in berseem + *gobhi sarson* (*Brassica napus* L. subsp. *Oliefera* var *annua*) intercropping system. Among different row spacings, Indian mustard [*Brassica juncea* L. Czernj & Cosson] at 100 cm, chinese cabbage (*Brassica chinensis* L.) at 150 cm and *gobhi sarson* at 200 cm apart rows when intercropped with broadcast sown berseem gave higher fodder yield than other treatments. In berseem + Indian mustard and berseem + *gobhi sarson* intercropping system, the highest green fodder yield was recorded when sown 100 cm apart and given 2 fodder cuttings. However, in berseem + chinese cabbage, broadcast sowing resulted in the maximum fodder yield. Sole crop of berseem gave its maximum seed yield. An intercropping of berseem with chinese cabbage or *gobhi sarson* caused little reduction in its yield compared to sole crop of berseem. Seed yield of berseem in berseem + Indian mustard (broadcast sown) or Indian mustard given 1 or 2 fodder cuttings was significantly higher than Indian mustard sown in wider rows or when left uncut. In berseem + Chinese cabbage intercropping, seed yield of berseem in wider row spacing was significantly higher than its narrow row spacing or broadcast sowing. The intercropping with *Brassica* crops decreased their respective yields compared to their sole crop yields. Maximum seed yield of Indian mustard or chinese cabbage was obtained when grown as sole crop (uncut). However, seed yield of *gobhi sarson* even after 1 cutting was similar to that of uncut *gobhi sarson*.

Key words : berseem, Chinese cabbage, fodder yield, *gobhi sarson*, intercropping, Indian mustard, seed yield

Forages are the mainstay of animal production. Low productivity of milch animals is mainly due to their poor nourishment caused by inadequate availability of fodders. Milk yield can be sustained on forage based ratio containing mixture of legume and non-legume crops (Mudgal 1988). Berseem is an important fodder crop of multicut nature with rapid growth after cuttings, gives high tonnage and provides fodder of excellent palatability. Due to acute shortage of green fodder, berseem is frequently cut for fodder and not allowed to set seed. Shortage of good quality seed is a major bottleneck in the production of forage crops. Traditionally, it is grown in mixture with different cereal and oilseed crops to obtain higher green fodder yield. Intercropping can increase the production and productivity of crops by better utilization of growth resources (Willey 1979). Fodder and seed yields of berseem are likely to be influenced by the spatial arrangement and cutting management of different intercrops, viz mustard, *gobhi sarson* and Chinese cabbage. Since

information on this aspect is lacking, the present investigation was conducted to study the effect of row spacing and cutting management of different crops on the fodder and seed yield of berseem in the intercropping systems.

MATERIALS AND METHODS

Field investigation was conducted at the University, Hisar during *rabi* season of 1993-94 and 1994-95. Soil was medium in available N (165 kg/ha) and available P (17 kg/ha) and rich in available K (372 kg/ha). Three independent experiments of intercropping of Indian mustard (*Brassica juncea* L. Czern & Coss) or Chinese cabbage (*Brassica chinensis* L.) or *gobhi sarson* (*Brassica napus* L.) with berseem (*Trifolium alexandrinum* L.) were laid out in three replications in randomised complete block design. Berseem as sole crop as well as in the intercropping systems was sown by broadcast method. Total fourteen treatments in each experiment tried were T₁, berseem - sole crop; T₂, berseem + mustard/Chinese cabbage/*gobhi sarson* (broadcast sown); T₃, berseem + mustard/Chinese cabbage/*gobhi sarson* (100 cm spacing)- uncut; T₄, berseem + mustard/Chinese cabbage/*gobhi sarson* (100 cm spacing) - one cutting; T₅, berseem +

¹National Fellow

²Assistant Agronomist, Punjab Agricultural University, Regional Research Station, Gurdaspur 143 521

Table 1 Effect of row spacing and cutting management of intercrops on the total green fodder yield in berseem based intercropping systems

Treatment	Total green fodder yield (tonnes/ha)		
	Berseem	Berseem	Berseem
	+ Indian mustard	+ Chinese cabbage	+ Gobhi sarson
Berseem - sole crop	58.5	68.5	65.7
Indian mustard / Chinese cabbage / gobhi sarson - sole crop			
Uncut			
One cutting		32.9	27.8
Two cuttings		45.5	40.5
Berseem + mustard/Chinese cabbage/gobhi sarson - broadcast sown	61.1	72.5	73.1
Berseem + mustard/Chinese cabbage/gobhi sarson - row spacing 100 cm	60.5	61.4	68.6
Berseem + mustard/Chinese cabbage/gobhi sarson - row spacing 150 cm	58.5	65.1	67.7
Berseem + mustard/Chinese cabbage/gobhi sarson - row spacing 200 cm	55.6	56.2	70.2
Berseem + mustard/Chinese cabbage/gobhi sarson - uncut	53.6	52.2	61.5
Berseem + mustard/Chinese cabbage/gobhi sarson - one cutting	60.3	62.6	70.6
Berseem + mustard/Chinese cabbage/gobhi sarson - two cuttings	60.8	67.9	74.4
CD (P=0.05)	0.60	0.37	0.40

mustard/Chinese cabbage/ gobhi sarson (100 cm) - two cuttings; T₆, berseem + mustard/Chinese cabbage/gobhi sarson (150 cm spacing) - uncut; T₇, berseem + mustard/Chinese cabbage/gobhi sarson (150 cm spacing) - 1 cutting; T₈, berseem + mustard/Chinese cabbage/gobhi sarson (150 cm spacing) - two cuttings; T₉, berseem + mustard/Chinese cabbage/gobhi sarson (200 cm spacing) - uncut; T₁₀, berseem + mustard/Chinese cabbage/ gobhi sarson (200 cm spacing) - one cutting; T₁₁, berseem + mustard/Chinese cabbage/gobhi sarson (200 cm spacing) - two cuttings; T₁₂, sole crop of

mustard/Chinese cabbage/gobhi sarson (45 cm apart rows) - uncut; T₁₃, sole crop of mustard/Chinese cabbage/gobhi sarson (45 cm apart rows) - one cutting; T₁₄, sole crop of mustard/Chinese cabbage/gobhi sarson (45 cm apart rows) - two cuttings.

The crops were simultaneously sown on 5 October in both years. Gross plot size was kept as 6 m × 5 m and the net plot was kept as 5 m × 4 m. All the crops were raised as per the recommended practices except for treatments. Nutrients were applied @ 25 kg N and 70 kg P₂O₅/ha to berseem and 80 kg

Table 2 Effect of row spacing and cutting management of intercrops on their seed yield in berseem based intercropping systems

Treatment	Seed yield (tonnes/ha)					
	Berseem + Indian mustard intercropping		Berseem + chinese cabbage intercropping		Berseem + gobhi sarson intercropping	
	Berseem	Mustard	Berseem	Chinese cabbage	Berseem	Gobhi sarson
Berseem - sole crop	0.65		0.69		0.66	
Indian mustard/ Chinese cabbage/gobhi sarson - sole crop						
Uncut		1.30		0.46		1.65
One cutting		0.30		0.0		1.52
Two cuttings		0.0		0.0		0.23
Berseem+mustard/Chinese cabbage /gobhi sarson (broadcast sown)	0.58		0.57		0.65	
Berseem + mustard/Chinese cabbage/gobhi sarson						
100 cm	0.54	0.25	0.59	0.10	0.63	0.72
150 cm	0.58	0.24	0.68	0.11	0.64	0.78
200 cm	0.50	0.24	0.67	0.08	0.65	0.69
Berseem + mustard/Chinese cabbage/gobhi sarson						
Uncut	0.50	0.63	0.62	0.29	0.62	1.14
One cutting	0.56	0.10	0.66	0.0	0.64	0.92
Two cuttings	0.56	0.0	0.67	0.0	0.66	0.14
(CD P=0.05)	0.03	0.08	0.08		NS	0.42

Table 3 Effect of row spacing and cutting management of intercrops on the seed yield attributes of berseem

Treatment	Berseem + mustard			Berseem + chinese cabbage			Berseem + gobhi sarson		
	No. of capsules /0.25 m ²	Seeds/capsule	1000 seed wt (g)	No. of capsules	Seeds/capsule /0.25 m ²	1000 seed wt. (g)	No. of capsules	Seeds/capsule /0.25 m ²	1000 seed wt. (g)
Berseem - sole crop	266	44.2	2.40	266	43.6	2.70	277	45.8	2.79
Berseem+mustard/Chinese cabbage/ gobhi sarson (broadcast sown)	267	47.2	2.30	280	53.8	2.31	285	50.5	2.84
Berseem + mustard/Chinese cabbage/ gobhi sarson									
100 cm	278	46.3	2.22	272	47.4	2.32	261	44.5	2.52
150 cm	284	44.8	2.09	267	50.3	2.29	270	47.7	2.63
- 200 cm	272	46.2	2.22	271	48.0	2.33	270	47.6	2.67
Gobhi sarson									
- Uncut	277	45.4	2.12	273	49.7	2.28	253	44.7	2.43
- One cutting	276	45.4	2.22	267	48.0	2.33	272	46.6	2.65
- Two cutting	279	45.7	2.18	270	47.9	2.33	275	48.6	2.74
(CD (p=0.05))	NS	NS	NS	NS	3.3	0.2	16.4	02.8	0.30

N and 30 kg P₂O₅/ha to *Brassica* crops (Indian mustard, chinese cabbage and *gobhi sarson*) raised as sole crops. In intercropping systems, the nutrients were applied on area basis. The N and P were applied through urea and single super phosphate, respectively. Nine irrigations were given to berseem and berseem based intercropping systems, whereas four irrigation were given to sole crops of mustard, chinese cabbage and *gobhi sarson* in each year.

First cutting of berseem and intercrops (as per treatments) was taken at about 60-65 days after sowing and the second about 30-35 days after the first cutting. Thereafter, berseem was harvested for fodder at regular intervals till mid-March after which the crop was left for seed setting. Green fodder and seed yield of all the crops was recorded. However, seed yield attributes, viz number of capsules, seeds/capsule and 1000-seed weight of only berseem were recorded. Seed crops of mustard, chinese cabbage and *gobhi sarson* were harvested at appropriate maturity stages in end March while berseem was harvested in the third week of May in both years. Results of the mean data have been presented. Likewise results of row spacings (mean of different cuttings) and cutting treatments (mean of different row spacings) have been presented.

RESULTS AND DISCUSSION

Green fodder yield

Intercropping of berseem with *Brassica* crops in different row spacings (100, 150 and 200 cm) and cutting management (uncut, 1 and 2 cuttings for fodder) significantly influenced the total green fodder yield (Table 1). The maximum increase over the sole crop of berseem was registered in berseem + *gobhi sarson* followed by berseem + chinese cabbage intercropping system. Among the intercropping systems, the highest total green fodder yield was registered when Indian mustard or Chinese cabbage was sown by broadcast method except in berseem + *gobhi sarson* intercropping system where

fodder yield with 2 fodder cuttings was slightly higher than its broadcast sowing. This increase in green fodder yield in broadcast sowing of intercrops with berseem might be due to their cutting for fodder along with berseem.

Among different row spacings, berseem intercropped with Indian mustard in narrow row spacing (100 cm), with Chinese cabbage in intermediate row spacing (150 cm) and with *gobhi sarson* in wider row spacing (200 cm) registered the highest total green fodder yield (Table 1). In berseem + chinese cabbage intercropping system, row spacing of 100 or 150 cm of Chinese cabbage gave significantly higher total green fodder yield than its row spacing of 200 cm. This might be due to more number of plants of Chinese cabbage in narrow row spacing than wider row spacing.

One fodder cutting of different *Brassica* crops intercropped with berseem gave significantly higher green fodder yield than when left uncut. Since there was no regeneration of mustard after 1 cutting, the green fodder yield (and also the seed yield) from its 1 and 2 cutting treatments was virtually the same. Moreover, Indian mustard alone is not preferred by the livestock as fodder; therefore its green fodder yield as a sole crop was not recorded. Chinese cabbage intercropped with berseem and given 2 fodder cuttings gave significantly higher total green fodder yield than its 1 cutting.

Among the three crops grown as sole crops, 2 cutting treatments of Chinese cabbage and *gobhi sarson* registered higher green fodder yield than their respective 1 cutting treatment. However, these yields were significantly lower than sole crop of berseem or their intercropping with berseem.

Interaction of row spacing and cutting management revealed that in berseem + Indian mustard intercropping system, the highest total green fodder yield was registered when mustard was sown in rows 100 cm apart and given 2 fodder cuttings (62.0 tonnes/ha) closely followed by broadcast sowing of Indian mustard with berseem (61.1 tonnes/ha).

Reduced green fodder yield in wider rows of Indian

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mustard uncut treatment in berseem + Indian mustard intercropping system might be due to better vegetative growth of Indian mustard offering severe competition to berseem for resources. In berseem + *gobhi sarson* intercropping system, sowing of *gobhi sarson* in rows at 100 cm and given 2 fodder cuttings (76.0 tonnes/ha) gave the maximum fodder yield closely followed by its sowing in rows at 200 cm and given 2 fodder cuttings (75.7 tonnes/ha). In case of berseem + Chinese cabbage intercropping system, broadcast sowing of Chinese cabbage gave the maximum green fodder yield (72.5 tonnes/ha) followed by its sowing in rows 150 cm apart and given 1 fodder cutting (71.0 tonnes/ha).

Seed yield

Seed yield of crops in different intercropping systems was significantly influenced by different treatments except that of berseem in berseem + *gobhi sarson* intercropping system. The maximum seed yield of berseem in general was registered in case of sole crop of berseem in all the intercropping system (Table 2).

Berseem + Indian mustard: In berseem + Indian mustard intercropping system, sole crop of berseem produced significantly higher seed yield than all other treatments while its intercropping with mustard in wider row spacing or that given no fodder cutting produced the lowest seed yield (Table 2). Seed yield of berseem in berseem + mustard (broadcast sown) or that given 1 or 2 cuttings was significantly higher than mustard sown in wider row spacing or left uncut.

Seed yield of Indian mustard was maximum when grown as sole crop and it was much higher than its yield in the intercropping system. Uncut mustard (sole crop) gave significantly higher seed yield than rest of the treatments. Uncut mustard + berseem also registered significantly higher seed yield of mustard than its one cutting in the intercropping system. Growth of Indian mustard was poor after its cutting for fodder resulting in very low seed setting and that given two cuts for Indian fodder did not give any seed. Seed yield of Indian mustard in its different row spacings when intercropped with berseem was similar.

Berseem + Chinese cabbage: Sole crop of berseem produced significantly lowest number of seeds/capsule and significantly highest 1000-seed weight than rest of the treatments (Table 3).

Number of capsules/0.25 m² was also influenced by different treatments. Thus sole crop of berseem registered significantly higher seed yield than its intercropping with Chinese cabbage (Table 2).

In the intercropping of berseem with Chinese cabbage in

wider row spacing of 150 or 200 cm, seed yield of berseem was significantly higher than its narrow row spacing (100 cm) or broadcast sowing. Chinese cabbage given 2 fodder cuttings produced slightly higher seed yield of berseem than 1 cut or no cut treatments under all row spacings and such difference between 2 cut and no cut treatment in 100 cm row spacing was significant.

The maximum seed yield of Chinese cabbage was produced when grown as sole crop (uncut) and its yield in the intercropping system decreased drastically. Chinese cabbage did not regenerate/sprout after cutting and therefore there was no seed setting in its cutting treatments.

Berseem + gobhi sarson: Differences in seed yield of berseem sown alone or intercropped with *gobhi sarson* in different row spacing and under different cutting treatments were not significant (Table 2). However, number of capsules/0.25 m² and 1000-seed weight of berseem in berseem + *gobhi sarson* (broadcast sown) intercropping system was significantly higher than berseem + *gobhi sarson* (uncut) intercropping system. The lowest seed yield of berseem in berseem + *gobhi sarson* (uncut) was probably because of the fact that uncut *gobhi sarson* offered severe competition to berseem for growth resources.

Regeneration and subsequent growth of *gobhi sarson* after first cutting was very good and it gave seed yield similar to that of uncut crop (as sole or as intercrop). However after second cutting, its regeneration was adversely affected resulting in very poor seed yield. Thus *gobhi sarson* was the best crop for intercropping with berseem.

Intercropping of berseem with *gobhi sarson* or even with Chinese cabbage caused little decrease in seed yield of berseem as compared to sole crop of berseem. Thus, for higher total green fodder yield, berseem can be intercropped with these *Brassica* crops. Sowing of these intercrops in wider row spacing and subsequently cutting them once or twice for fodder gave higher seed yield of berseem than narrow row spacing and uncut treatment of these intercrops. Among the three intercrops, *gobhi sarson* was the most compatible with berseem as it gave seed yield similar to sole crop of berseem in addition to its green fodder yield.

REFERENCES

- Mudgal V D. 1988. Forage for economic milk production from cattle and buffaloes. Paper presented at the Third International Rangeland Congress, held during 7-11 November at New Delhi.
- Willey R W. 1979. Intercropping - its importance and research needs. 1. Competition and yield advantages. *Field Crop Abstracts* 32 : 1-10.

Economic evaluation of an agroforestry system in hill zone of Karnataka

S M MUTANAL¹, B S NADAGOUDAR² and S J PATIL³

University of Agricultural Sciences, Dharwad 580 005

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ABSTRACT

An experiment involving arable crops, viz rice (*Oryza sativa* L.), maize (*Zea mays* L.), sunnhemp (*Crotalaria juncea* L.), silvicultural crops (*E. tereticornis* L.), *C. equisetifolia* J. R. & G. Forst, *A. molucana* (L.) Benth, *T. grandis* L.) F., *D. sissoo* Roxb), horticultural crop (sapota) and pasture (grass *Panicum maximum* L.) was initiated in black clayey soils of Prabhunagar, Dharwad during 1976. Sapota (*Achras sapota* L.) was planted at 10 m apart and 3 trees were planted between 2 plants of sapota. Grass was planted in 1 m wide strip on either side of sapota + tree species. At the end of 17 years, trees were felled. Income from trees was higher in field crops + sapota with inclusion of teak and eucalyptus trees. Higher income from sapota was in sole crop and with *A. molucana*. Total average income from field crop + sapota + teak was higher by 46 % than with field crops + sapota. Net pay back value and benefit : cost ratio were higher in sapota+teak (Rs 1633 176 and 9.31 respectively) and sapota + *sissoo* (Rs 6754 08 and 4.34 respectively).

Key words: agroforestry system, net pay back value, benefit : cost ratio, silvicultural crop

Agroforestry is integration of woody perennials with arable crops as an alternate land-use system in tropical world (Baumer 1991). Demand for food and fuel can be met through sustainable land use systems of agroforestry. A typical agroforestry system will allow economic and ecological interactions between woody and non-woody components and also to increase, sustain and diversify the total land output (Nair 1989). Among different components, there should be positive interaction between trees and crops. An economically viable agroforestry model is accepted by the farmers. In the present investigation an economic evaluation of an agroforestry system comparing the sole sapota and agricultural crops was made.

MATERIALS AND METHODS

An experiment was initiated during 1976 in black clayey soils of the Agricultural Research Station, Prabhunagar (15°27' N latitude 74°46' E longitude and 678 msl (Dharwad). It is located in hill zone of Karnataka with annual rainfall of 1 124 mm. The experiment involved arable crops rice- (*Oryza sativa* L.), maize- (*Zea mays* L.), sunnhemp (*Crotalaria juncea* L.), horticultural crop (sapota-*Achras sapota* L.), silvicultural crops (*Eucalyptus tereticornis* L., *Albizia molucana* (L.) Benth, *Casuarina equisetifolia* J.R. & G. Forst, *Tectona grandis* L.f and *Dalbergia sissoo* Roxb). Sapota was planted at a recommended spacing of 10 m × 10 m. Tree species

were planted in between two sapota plants and rows being across the slope. The first tree was at 3 m from sapota and subsequent 2 trees at 2 m, thus leaving 3 m again between last tree and next sapota plant. On either side of sapota and tree species, guinea grass (*Panicum maximum* L.) was planted in a strip of 1 m wide. In between two rows of sapota + trees, field crops were grown, viz paddy for 6 years, maize for 3 years, sunnhemp for 4 years under rainfed conditions. Annually fertilizers were applied @ 40:20:20, 40:20:10 and 10:5:5 NPK kg/ha for paddy; maize and sunnhemp respectively. All the trees were felled in short rotation species- casuarina, eucalyptus, *A. molucana* and only 2 trees on either side of sapota were felled in long rotation species- teak and *sissoo*. Due to the growth of sapota and tree species initial 1 m strip became 5.8 m after 17 years. Gross/net plot size was 0.5 ha with randomised block design. Each treatment consists of 50 sapota trees and 150 trees of each tree species. Hence, the space available for agricultural crop reduced gradually depending upon the growth of sapota plants and crop cultivation became difficult after 13 years. As a result growing of arable crops was stopped from 13th year onwards.

RESULTS AND DISCUSSION

Interaction between different components

Sapota fruit yield (Table 1) was higher with sapota+FC grown alone (2.47 tonnes/ha/year) followed by field crops + sapota + *A. molucana* (1.83 tonnes/ha/year) and field crops+sapota+casuarina (1.58 tonnes/ha/year). Lowest fruit yield was observed in sapota + field crops+*E. Tereticornis* (1.28 tonnes/ha/year) and sapota + field crops + *T. grandis*

¹Scientist (S1) Agroforestry, ²Senior Scientist (Agroforestry) and ³Scientist (S-2) Agroforestry, Forestry Department

Table 1 Sapota fruit yield and growth of tree species in agroforestry after 17 years

Agroforestry component	Sapota fruit yield (tonnes/ha/year)	Height (m)	Tree species dbh (cm)	Volume (M ³ /tree)	(M ³ /ha)
Field crops+sapota (control)	2.47				
Field crops+sapota +eucalyptus	1.28	20.4	83.5	0.912	273.6
Field crops+sapota + <i>A. molucala</i>	1.83	14.40	122.0	0.552	165.6
Field crops+sapota +casuarina	1.58	11.70	62.9	0.262	78.6
Field crops+sapota +teak	0.55	9.40	46.5	0.140	42.0
Field crops+sapota + <i>sissoo</i>	1.54	7.70	47.8	0.118	35.4

Table 2 Income from field crops, sapota and tree species as affected by different agroforestry systems after 17 years

Agroforestry component	Field crops (Rs/ha)	Sapota (Rs/ha)	Tree species (Rs/ha)	Total income over the control	Incr- ease in back value 15%	Net pay ratio	Benefit: cost ratio
Field crops+sapota (Control)	27 200	102 476	129 696				
Field crops+sapota +eucalyptus	19 312	53 074	67 883	140 269	8	— 872 096	0.33
Field crops+sapota + <i>A. molucana</i>	20 638	78 319	33 317	13 2274	2	— 747 156	0.22
Field crops+sapota +casuarina	19 329	58 786	15 554	93 669	— 28	— 30 674	0.85
Field crops+sapota +teak	24 803	16 558	14 7924	18 9285	46	16 33 176	9.31
Field crops+sapota + <i>sissoo</i>	20 655	58 157	56 613	13 5425	4	675 408	4.34

(0.55 tonne/ha/year). Greater reduction of sapota yield in eucalyptus and teak is due to the dominating growing habit and canopy structure of eucalyptus. Both casuarina and sissoo have positive influence on fruit yield of sapota due to their sparse canopy and low moisture requirement during initial years of establishment.

Among the tree species eucalyptus recorded the highest timber volume (0.912 M³/tree) followed by *A. molucana* (0.552 M³/tree) whereas lowest volume of trees was noticed in *D. sissoo* (0.118 M³/tree). This may be due to slow growth (height and dbh) of trees (sissoo and teak) resulting in lesser timber volume as compared to fast growing tree species.

Income from perennial components

Income from sapota trees was worked out on the basis of yield and market price (Table 2). Sapota grown with field crops had higher total income (Rs 102 476/ha) followed by sapota+field crop+*A. molucana* (Rs 78 319/ha) and casuarina (Rs 58 786/ha). This is due to the better growth of sapota under various tree species. The lowest income was observed in sapota + field crops + eucalyptus (Rs 53 074) and field crops + sapota+teak (Rs 16 558/ha). Among tree species, teak recorded higher income (Rs 147 924/ha) wherein felling of only 2/3 trees was done as compared to felling of all trees in eucalyptus (Rs 67 883/ha) *A. molucana* (Rs 33 317/ha) and casuarina (Rs 15 554/ha). Differential timber value of different tree species influenced the income from tree species rather than their volume.

Total income from agri-silvi-horti system was higher in field crops+sapota+teak (Rs 189 285/ha) followed by sapota+eucalyptus (Rs 140 269/ha) and sapota + *D. sissoo* (Rs 11 35 425/ha). This is due to higher income from teak and eucalyptus timber though the fruit yields were low in these treatments.

Economic analysis

The economic analysis (Table 2) of income from different treatments was carried out at the end of 17 years. The NPVs were negative for agroforestry system with eucalyptus, casuarina and *Albizia molucana* indicating that these species are no way better than the system without tree component. The benefit: cost ratio (BCR) was highest in agroforestry systems with teak (9.31) followed by sissoo (4.34).

It may be concluded that the system with field crops + sapota and teak/sissoo are economically viable as compared to other tree species. Similarly higher total income was obtained with field crop+teak+papaya on red gravelly soils of Dharwad (Madiwalar *et al.* 1996) and also higher net returns with integration of tree + agricultural crop at Bijapur under dryland conditions (Korwar 1992).

REFERENCES

- Baumer M. 1991. Animal production, agroforestry and similar techniques. *Agroforestry abstract* 4 (9) : 179-98.
- Nair P K R. 1989. *Agroforestry Systems in Tropics*, pp 664. Kluwer Academic Dordrecht, Netherlands.

- Korwar G R. 1992. 'Studies on alley cropping and agro-silvi culture system in black soils under dryland agricultural conditions'. Ph D thesis, UAS, Dharwad.
- Madiwalar S L, Nadagoudar B S, Mutanal S M and Patil S J. 1996. Economic evaluation of agri-silvi-horti-pastoral

system in transitional tract of Dharwad. *Proceedings of IUFRO, DNAES International Meet-Resources Inventory Techniques to Support Agroforestry and Environment*, held during 1-3 October 1996 at Chandigarh, pp 287-9.

Mineralogy and forms of potassium in red yellow latosol of a guava (*Psidium guajava*) tree orchard

WILLIAM NATALE¹, J MARQUES JÚNIOR², A E BOARETTO³ and F L SIMÕES⁴

UNESP - Universidade Estadual Paulista, 14870-000, Jaboticabal, São Paulo, Brasil

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ABSTRACT

A trial was conducted during 1994-95 to study the effect of potassium fertilization on a guava (*Psidium guajava* L.) culture for 3 years. The control plots (without K) showed fruit production and potassium exportation that did not agree with the levels obtained by chemical analysis of the soil. Physical, chemical, mineralogic and morphologic analyses were performed on the red yellow latosol to identify minerals able to supply potassium, with emphasis on the fact that guava trees have a considerably widespread root system. The results obtained confirmed the presence of minerals in this soil that can supply potassium to the trees through weathering. Feldspars were identified in the silt fraction and micas in the clay fraction by X-ray diffractometry. The determination of total potassium revealed that the silt fraction of the soil had the largest absolute amounts of potassium, followed by clay. However, in view of its greater content, clay was the fraction that contributed most to the total amounts of potassium detected.

Key words: *Psidium guajava*, Brazil, K, feldspars, mica, fertiliser

In highly weathered soils, commonly found in the tropics, the exchangeable form has been used to determine the availability of potassium to plants. (Raij 1991). Most Brazilian soils have kaolinite, gibbsite and iron oxides, such as hematite and goethite predominate in the clay fraction, and quartz predominates in the sand fraction. However, many reports are available about various crops set up in soils with low potassium levels that do not show a significant response to the addition of potassium (Rosolem 1980, Rosolem *et al.* 1993). The explanations proposed for this fact emphasize the existence of other forms of K in soil in addition to the exchangeable form that can be utilized by plants (Mascarenhas *et al.* 1981, Nachtigall and Vahl 1991, Fernandes *et al.* 1993). According to these investigators, non-exchangeable potassium commonly originates in minerals such as mica in the clay fraction and orthoclase in the silt and fine sand fractions.

Plant roots may result biological weathering, releasing potassium from primary minerals such as mica (Hinsinger *et al.* 1992, Hinsinger and Jaillard 1993, Niebes *et al.* 1993). The rapid mineralogic changes produced by the roots support that non-exchangeable forms make a significant potassium contribution to the plants especially near the more active

portion of the roots.

In a trial concerning potassium fertilization conducted on guava culture for 3 years, Natale (1993) reported that control plots (without K) showed fruit production and potassium exportation that did not agree with the levels obtained by chemical analysis of the soil. During the third year of the trial the trees on the control plots gave a yield of 57 tonnes fruits/ha. The orchard had the red yellow latosol in the 0-20 cm soil layer, a content of exchangeable K of 0.4 mmolc/dm³ (very low), or approximately 32 kg potassium/ha. Approximately 1 769 g K/fruit/tonne exported, on average, just for fruit production, a fact that would require approximately 100 kg K/ha considering 100% efficiency in K utilization by the trees.

The objective of the present study to obtain more detailed information about soil mineralogy in order to interpret the biological phenomenon observed in guava culture.

MATERIALS AND METHODS

The study was carried out (1994-95) on red yellow latosol (Typic Hapludox - in the municipality of São Carlos, São Paulo, Brazil on a guava orchard. The site is located at 21°15' latitude South and 48°18' longitude West, 840 m above sea level. The climate is C_{Wa} in the Köppen system (mesothermal with dry winters), with a mean temperature of <18°C in the coldest month and >22°C in the warmest month, and a mean annual rainfall of 1 495 mm. August is the driest month and December has the highest rainfall. The plants of 5-year-old 'Paluma' guava, vegetatively propagated spaced 7 m x 5 m,

¹Professor, Department of Soil and Fertiliser, Faculdade de Ciências Agrárias e Veterinárias de Jaboticabal (UNESP), ²Professor, FCAV/UNESP, ³Agronomist Engineer, FCAV/UNESP

⁴Associate Professor, Centro de Energia Nuclear na Agricultura, 13416-000 Piracicaba, SP, Brazil.

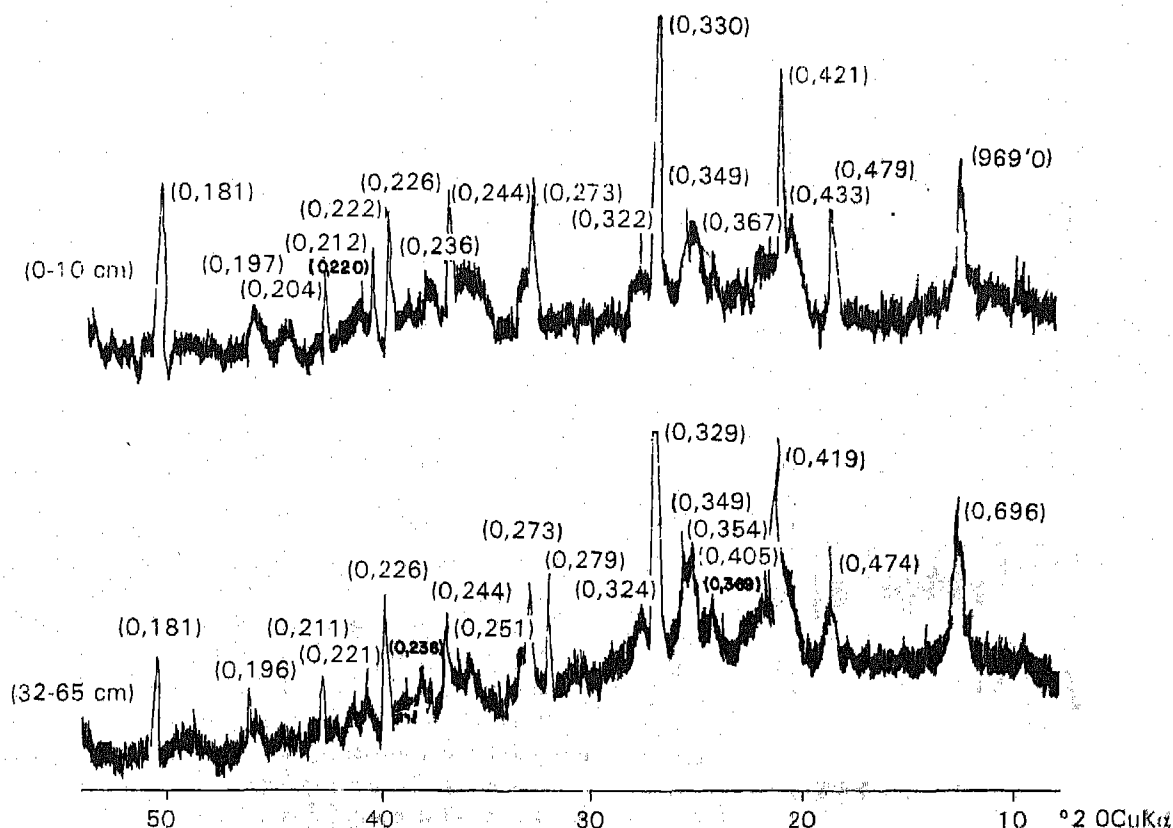


Fig 1 X-ray diffractogram of the silt fraction (oriented slide) of the latosol: (0-10 cm) - plagioclases with characteristics of anortine in the reflexes 0.479-0.322-0.226-0.197-0.181 nm; K feldspars, orthoclase and anorthoclase in the reflexes 0.646-0.421-0.367-0.349-0.330-0.273-0.220-0.212-0.204 nm. 32-65 cm-plagioclases in the reflexes 0.474-0.405-0.324-0.236-0.226-0.226-0.221-0.181 nm; feldspars in the reflexes 0.696-0.419-0.369-0.349-0.329-0.279-0.273-0.211 nm.

Table 1 Particle size distribution in the red yellow latosol of a guava tree orchard

Depth (cm)	Particle size distribution (g/kg)			
	Coarse sand	Fine sand	Silt	Clay
0-10	250	570	20	160
10-32	280	540	10	170
32-65	260	530	30	180
65-110	210	570	30	190
110+	220	540	40	200

was used.

Four trenches were dug between plants in the plant row, and soil material was collected to a depth of 350 cm in order to classify the morphology of the soil and its physical, chemical and mineralogic characteristics. Chemical analysis of the surface soil was: pH (CaCl₂) 4.7, organic matter 19 g/kg, P (resin) 30 mg/dm³, and K, Ca, Mg and H+Al 0.4, 12, 5 and 31 mmol/dm³ respectively.

Particle size distribution was determined by dispersal with 0.1 n NaOH and slow shaking for 24 hrs (Day 1965). Sand (2.00 to 0.20 mm and 0.20 to 0.05 mm) and silt (0.05 to 0.002 mm) were separated by the pipette method and clay

was separated by centrifugation (Jackson 1956).

Total potassium was determined in soil by perchloric hydrofluoric acid attack (Pratt 1965a) and also separately in clay without iron, in silt and in sand. Non-exchangeable soil potassium was determined by heating with 1N HNO₃ (Pratt 1965b), and also separately for the sand, silt and clay

Table 2 Total potassium and nonexchangeable potassium values in different particle fractions of red yellow latosol (mean of 4 replications)

Depth (cm)	K forms	Particle size distribution (mg/kg)			
		Coarse sand	Fine sand	Silt	Clay
0-10	Total	55	77	939	390
	nonexchangeable	<1	<1	148	61
10-32	Total	61	71	703	342
	nonexchangeable	<1	<1	62	49
32-65	Total	68	68	545	358
	nonexchangeable	<1	<1	21	47
65-110	Total	87	90	529	362
	nonexchangeable	<1	<1	15	34
110+	Total	77	84	571	348
	nonexchangeable	<1	<1	11	27

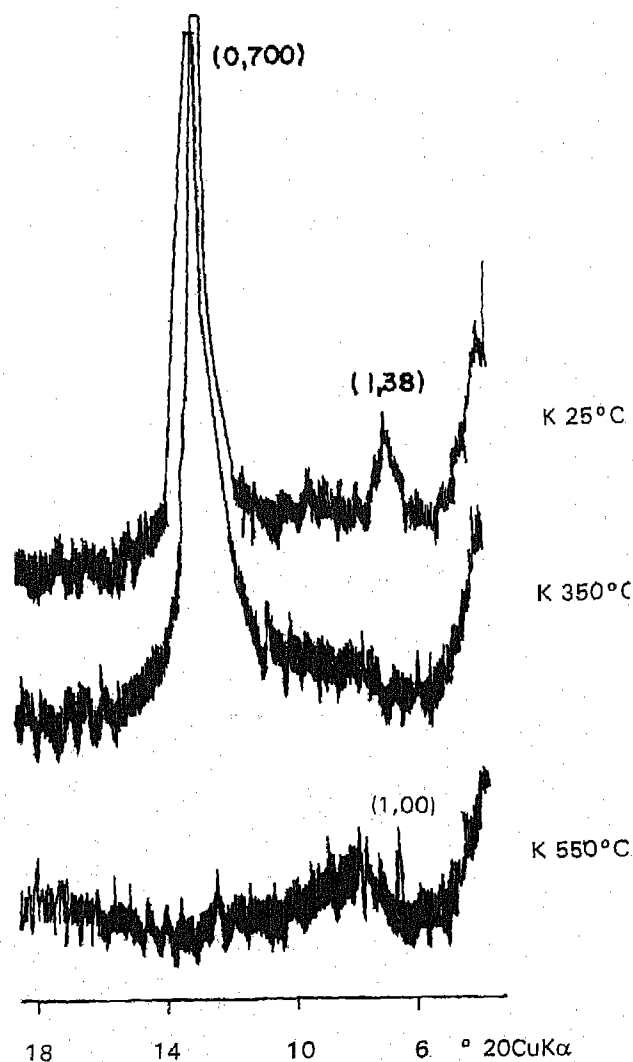


Fig 2 X-ray diffractogram of day without iron (d spacing in nm) of latosol (0-10cm) saturated with K at 25, 350 and 550°C. Vermiculite (EHE) in the reflex 1,38 (K25°C). Mecca in the reflex 1.00 (K 550°C)

fractions. Exchangeable soil K was determined by resin extractor (Raij 1991).

Silt and clay were subjected to mineralogic analysis by separation of the material in a centrifuge, and X-ray diffraction was determined using oriented slides. The clay fraction was saturated with magnesium and potassium at 25°C, and the fractions saturated with potassium were also heated to 350° and 550°C.

RESULTS AND DISCUSSION

There was no marked differentiation along the profile analyzed and that the profile obtained was typical of latosol (Table 1).

The determination of total potassium and of

Table 3 Total potassium, nonexchangeable potassium and exchangeable potassium levels determined in whole samples of red yellow latosol (mean of 4 replications)

Depth (cm)	Total K (HF) (mg/kg)	Nonexchangeable K (HNO ₃) (mg/kg)	Exchangeable K (Resin) (mg/kg)
0-10	157	70	60
10-32	156	49	24
32-65	108	9	8
65-110	118	8	8
110-150	118	13	8
150-200	118	13	8
200-250	127	10	8
250-300	127	14	8
300-350	118	10	4

nonexchangeable potassium showed that the silt fraction has the highest absolute levels of potassium followed by clay (Table 2) which is in agreement with the findings of Ricci *et al.* (1989) and Silva *et al.* (1995). However, because it was present in largest amounts, clay was the fraction that most contributed to the potassium levels observed. Both potassium forms decrease with depth, more markedly so in silt than in clay (Table 2). The nonexchangeable K values determined in fine and coarse sand was extremely low (< 1 mg/kg) throughout the profile indicating a small potential contribution to the K supply for the trees on the part of these fractions.

Table 3 shows the results obtained for exchangeable, nonexchangeable and total K levels to a depth of 350 cm in whole soil samples. Potassium concentration was higher at depths of 0-10 and 10-32 cm regardless of K form probably due to the higher levels of organic matter. It can also be seen that below the depth of 32 cm total K values are practically constant throughout the profile resulting in the low textural variation typical of latosols (Table 1).

On the basis of the total K levels in the 0-20 cm soil layer, it can be estimated that the soil has a K reserve of the order of 375 kg K₂O/ha.

The results of X-ray diffraction for the silt fraction (Fig 1) showed the presence of K feldspars (orthoclase) as the dominant mineral. The presence of this mineral in the silt fraction supports the findings of several investigators who studied developed soils of arcose arenites. These data support those listed in Table 2, which shows the presence of total potassium and nonexchangeable potassium in the silt fraction. This may indicate the importance of the silt fraction which still presents some important minerals even in strongly weathered soils.

The presence of mica was recorded for the clay fraction (Fig 2 and 3). The contribution of this fraction in terms of total and nonexchangeable potassium (Table 2) and its levels in soil (Table 1) reveal its greater contribution in terms of potassium supply. The low intensity of the mica peak may

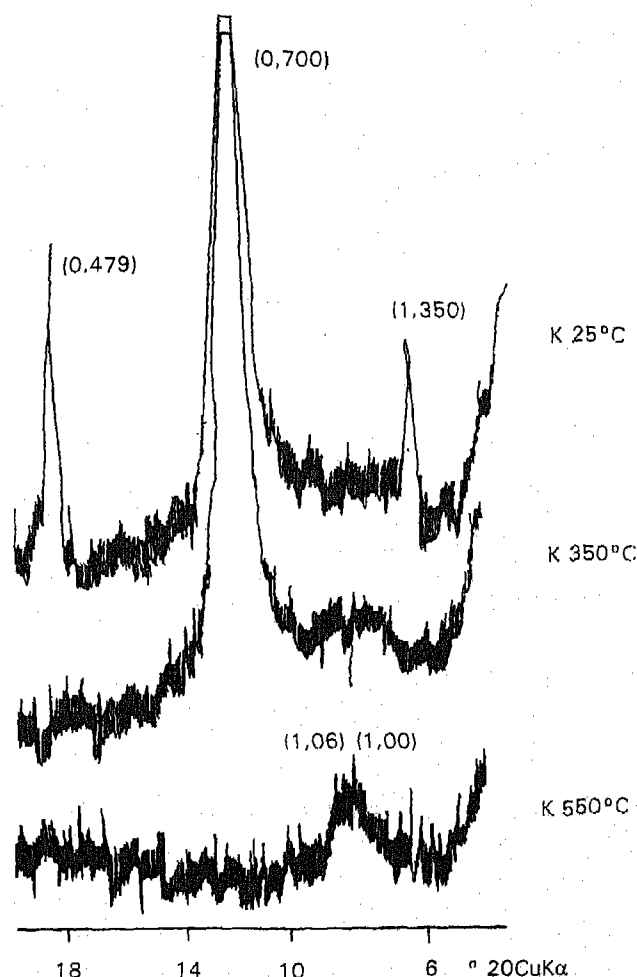


Fig 3 X-ray diffractogram of clay without iron (d spacing in nm) of latosol (32-65 cm) saturated with K at 25, 350 and 550°C, Gibbsite in the reflex (9.479); Kaolinite (0.700); vermiculite (EHE) (1.35); mica (1.06-1.00)

indicate its preferential presence in the fine or coarse clay fractions, which were not fractionated. Similar results were reported by Silva *et al.* (1995).

The data for mineral identification by X-ray diffraction plus the data obtained by chemical analysis revealed that the latosol contains potassium reserves in the form of primary minerals. Although these reserves are relatively small, they may explain the exportation of K to guava fruit observed in the fertilization trial which did not correspond to the levels determined by analysis of soil fertility (K resin).

The low values of nonexchangeable potassium, ie potassium levels available on a medium-term basis, may also explain the data obtained for the control guava trees which, even with extremely low exchangeable K levels in soil (either because of depletion of this form or because the trees were able to utilize small amounts of the element in other forms), gave approximately 57 tonnes fruits/ha, although they presented very strong symptoms of K deficiency (leaves first

showing reddish-brown margins with progression towards the main nervure and with later necrosis of these areas). Leaves analysis potassium levels of 1.2-1.3 g/kg, when adequate levels should be 14-17 g/kg (Natalé 1993).

These results should not be extrapolated to different environments but indicate that the potassium reserve of this soil, although not large, can satisfy the needs of the cultures for some time. This may indicate that in less weathered soils than the one studied here the contribution of nonexchangeable K may be even greater, explaining the absence of a response to the nutrient reported in several studies earlier. Thus, a more detailed knowledge of the mineralogy of the soil may lead a better understanding and regulation of aspects related to crop fertilization.

This knowledge does not reduce the importance of fertilization or minimize the need to practise it, but serves to indicate that the presence of minerals such as those determined in the present study may influence the results shown by the trees.

REFERENCES

- Day P R. 1965. Particle fraction and particle size analysis. (in) *Methods of Soil Analysis*, pp 545-66. Black C A (Ed). American Society of Agronomy, Madison.
- Fernandes D M, Rossetto C A V, Ishimura I and Rosolem C A. 1993. Nutrição da soja e formas de potássio no solo em função de cultivares e adubação potássica. *Revista Brasileira de Ciência do Solo* 17 405-10.
- Hinsinger P and Jaillard B 1993. Root-induced release of interlayer potassium and vermiculitization of phlogopite as related to potassium depletion in the rhizosphere of ryegrass. *Journal of Soil Science* 44 : 525-34.
- Hinsinger P, Jaillard B and Dufey J E. 1992. Rapid weathering of a trioctahedral mica by the roots of ryegrass. *Soil Science Society of America Journal* 56 : 977-82.
- Jackson M L. 1956. *Soil Chemical Analysis*. Madison, Wisconsin.
- Mascarenhas H A A, Valadares S M A, Torta C L and Bulisani E A. 1981. Adubação potássica na produção de soja, nos teores de potássio nas folhas e na disponibilidade de potássio em latossolo roxo distrófico de cerrado. *Bragantia* 40 : 125-34.
- Nachtigall G R and Vahl L C. 1991. Capacidade de suprimento de potássio dos solos da região Sul do Rio Grande do Sul. *Revista Brasileira de Ciência do Solo* 15 : 37-42.
- Natalé W. 1993. *Diagnose da nutrição nitrogenada e potássica em duas cultivares de goiabeira (Psidium guajava L.), durante três anos. (Doctoral thesis) - ESALQ/USP, Piracicaba.*
- Niebes J F, Dufey J E, Jaillard B and Hinsinger P. 1993. Release of nonexchangeable potassium from different size fractions of two highly K-fertilized soils in the rhizosphere of rape (*Brassica napus* cv Drakkar). *Plant and Soil* 155/156 : 3-406.
- Pratt P F. 1965a. Digestion with hydrofluoric and perchloric acids for total potassium and sodium. (in) *Methods of Soil Analysis*, pp 1 019-21. Black C A. American Society of Agronomy, Madison.
- Pratt P F. 1965b. Potassium. (in) *Methods of Soil Analysis*, pp 1 22-30. Black C A. American Society of Agronomy, Madison.
- Raj B van. 1991. *Fertilidade do solo e adubação*. Ceres/Potafos, Piracicaba, São Paulo, p 343.

- Ricci M S F, Defelipo B V, Costa L M and Resende S B. 1989. As frações granulométricas do solo como reserva de potássio para as plantas. *Revista Brasileira de Ciência do Solo* 13 : 181-6.
- Rosolem C A. 1980. *Nutrição Mineral e Adubação da Soja*. Instituto da Potassa e do Fósforo/Instituto Internacional da Potassa, Piracicaba, (Boletim Técnico, 6).
- Rosolem C A, Bessa A M and Pereira H F M. 1993. Dinâmica do potássio no solo e nutrição potássica de soja. *Pesquisa Agropecuária Brasileira* 28 : 1 045-54.
- Silva D N, Meurer E J, Kämpf N and Borkert C M. 1995. Mineralogia e formas de potássio em dois latossolos do Estado do Paraná e suas relações com a disponibilidade para as plantas. *Revista Brasileira de Ciência do Solo* 19 : 433-9.

Effects of tillage practices on growth and yield of cassava (*Manihot esculenta*) and some soil properties in Ajibode, South-western Nigeria

EMILOLORUN A AIYELARI¹, NYAUDOH U NDAEYO² and AKINOLA A AGBOOLA³

University of Ibadan, Nigeria

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ABSTRACT

A study was conducted in 1994 and 1995 at Ibadan, Nigeria to evaluate the productivity of cassava (*Manihot esculenta* Crantz) and soil properties and dynamics under some tillage practices. Results revealed that tillage practices had no significant effect on sprouting percentage in 1994 but in 1995, heap treatment was significantly ($P < 0.05$) higher than others. Tillage had no marked effect on cassava height in both years while number of leaves only differed significantly from 8 months after planting with HP treatment being higher than others. Stem girth showed no marked differences among treatments in both years. Similarly, in both years, cassava fresh root yield and yield components were not significantly affected by tillage practices. The No-till slash and burn treatment showed significantly higher soil bulk density at planting in both years than other treatments. Generally, soil chemical properties were not markedly affected by the tillage practices. The highest cost of production was observed under no-till slash and burn while ridge gave the highest economic returns. For successful growing of cassava under reduced tillage practices is practicable in this agro-ecological zone.

Key words: tillage, cassava, soil properties, economic returns, Nigeria

Growth, development and consequently, yield of crops are more highly influenced by the available soil moisture than any other single factor (Alem 1993). In most cases, the available soil moisture is highly associated with the precipitation of the season. Crop stresses most often become severe when the available soil moisture is reduced considerably during seasons with short or prolonged dry spells. As a result, crop production varies significantly from season to season and yields are unstable. Consequently, appropriate tillage practice has been one of the agronomic measures adopted to ensure optimum soil moisture content and, invariably optimum crop yield in some location and soil type. However, tillage practices can induce profound changes in fertility status, and the changes may be manifested in good or poor performance of crops. The zero or minimum tillage systems have been tried and showed some promising results compared to conventional tillage systems (Ike 1985). Some workers (Zheng *et al.* 1992) have on the other hand noted superiority of crops grown on tilled plots over that of zero-tilled plots in some agro-ecological zones; while others (Ohiri and Ezumah 1990, Ndaeyo *et al.* 1995) observed no significant differences among tillage treatments. Hence, a study was initiated to assess the applicability of some tillage practices to cassava production on an Alfisol and their influence on some soil properties.

MATERIALS AND METHODS

The experiment was conducted during the 1994 and 1995

planting seasons at the research farm of the University located at Ajibode near the International Institute of Tropical Agriculture (IITA), Ibadan (latitude 07°45'N, longitude 03°45'E with an altitude of 220 m above sea level). The zone has a bi-modal pattern of rainfall, with the first rainy season commencing from April to July, dry spell in August is followed by the second rainy season in September to November. The annual rainfall and evaporation rates, mean monthly wind speed, solar radiation, atmospheric temperature and relative humidity and annual number of rainy days was 1063.9 mm, 1416.7 mm, 3.6 km/hr, 15.1 ml/m²/day, 26.4°C, 72% and 99 respectively, in 1994. The corresponding values for 1995 were 1045.1 mm, 971.1 mm, 2.5 km/hr, 10.1 ml/m²/day, 18°C, 51% and 75 (Anderson and Ingram 1993). The soil is well-drained sandy soil of Egbeda Series (Smyth and Montgomery 1962) and of the broad group of tropical Alfisol (FAO 1965).

In each year, there were 4 treatments in randomized block design in 4 blocks. Block size was 46 m × 10 m with inter block spacing of 2 m while a plot size was 10 m × 10 m with interplot spacing of 2 m. The tillage treatments consisted of: (i) No tillage, plots slashed manually, followed by *in-situ* burning of the debris after drying; (ii) No tillage, vegetation sprayed with a herbicide, glyphosphate at the rate of 1.0 kg/ha; (iii) Heaping with heaps made after slashing the vegetation using native hoe and (iv) Ridging, with ridges made with a tractor-drawn disc ridger after ploughing.

The same tillage method was maintained on each plot for

Table 1 Effects of tillage practices on cassava storage root yield and yield components

Treatment	1994				1995			
	Tuber/plant	Tuber length (cm)	Tuber diameter (cm)	Yield (tonnes/ha)	Tuber/plant	Tuber length (cm)	Tuber diameter (cm)	Yield (tonnes/ha)
Heaping	6.1	39.6	16.9	21.6	7.3	41.7	18.1	23.1
No-till+herbicide	4.5	36.3	15.5	17.7	5.6	40.1	16.9	18.3
Ridging	7.0	41.5	17.3	24.0	7.7	42.5	21.2	25.9
No-till+slash and burn	4.7	37.8	15.8	18.5	5.1	39.7	19.9	20.1
SEm ($\pm$)	0.8	3.4	2.1	4.3	0.4	5.6	4.2	5.4
CV (%)	6.7	15.1	12.3	13.4	10.5	4.4	11.2	17.2
	NS	NS	NS	NS	NS	NS	NS	NS

NS, Not significant

Table 2 Effects of tillage practices on soil moisture content and bulk density

Treatment	1994						1995					
	At planting		6 MAP*		9 MAP		At planting		6 MAP		9 MAP	
			Moisture content (%)	Bulk density (%)	Moisture content (%)	Bulk density (%)			Moisture content (%)	Bulk density (%)	Moisture content (%)	Bulk density (%)
Heaping	12.47	1.35	10.55	1.39	13.15	1.38	18.30	1.33	15.01	1.36	18.8	1.35
No-till + herbicide	14.07	1.45	11.00	1.41	14.95	1.40	24.41	1.42	18.40	1.40	21.3	1.41
Ridging	12.05	1.34	10.15	1.38	13.13	1.37	19.80	1.32	16.31	1.36	18.7	1.38
No-till + slash and burn	14.30	1.49	11.37	1.45	15.51	1.42	23.83	1.46	19.50	1.44	22.7	1.44
SEm ($\pm$)	3.42	0.12	3.80	0.32	3.04	0.31	4.40	0.14	3.27	0.39	2.39	0.39
CV (%)	12.42	13.40	8.32	17.21	12.41	9.49	14.56	15.03	14.31	12.41	14.11	13.42
LSD	NS	0.01	NS	NS	NS	NS	NS	0.03	NS	NS	NS	NS

MAP*, Months after planting; NS, not significant

the entire period of investigation.

In both years, planting was done in July. The cultivar 'TMS 30572' cassava (high yielding, low cyanide content and resistant to bacterial blight and mosaic disease) obtained from agronomy department of the university was planted manually at a spacing of 1 m $\times$ 1 m thereby giving 10 000 stands/ha. One stem cutting of about 25 cm length was planted per stand at an angle of about 45° with almost ¾ of its length buried in the soil. Weeding was done manually from the fourth week after planting.

The parameters determined were sprouting percentage, plant height, number of leaves, stem girth, cassava fresh root yield and yield components, cost of production and economic returns to management. Sprouting count was taken at 3 weeks after planting by counting the total number of sprouted plants against total number of cuttings planted and expressed in percentage. Twenty plants per plot were tagged for plant height, stem girth and number of leaves determination. Yield and yield components were determined by harvesting cassava from an area of 4 m² each at the top, middle and bottom of each plot and the averages pooled. Soil moisture content and bulk density were determined using core method (Blake and Hartage 1986).

Soil samples (0 - 15 cm) were collected before and after

the investigations to determine changes in soil nutrient status. The soil samples were processed and analyzed for the following parameters: soil pH by the glass electrode pH meter in 1:1 soil to water ratio; particle size by the hydrometer method; organic carbon by the Walkley-Black method (Anderson and Ingram 1993b); total N by micro-Kjeldahl method; while the available P was by the Bray's P1 method. Exchangeable cations were determined by extracting with neutral normal NH₄OAC. The flame photometer was used to read K, Na and Ca while Mg was read on the atomic absorption spectrophotometer. Exchangeable acidity was determined by titration method, while CEC was determined as the sum of exchangeable bases and exchangeable acidity. Base saturation was obtained as the per cent ratio of the total exchangeable bases to the effective cation exchange capacity. Partial budgeting was used to assess the cost of production and economic returns to management under different tillage practices (CYMMYT 1988).

RESULTS AND DISCUSSION

Sprouting percentage and plant height: Significant difference was observed only in 1995 (Fig 1) with heaping treatment (92.98%) showing superiority over no-till + herbicide (80.16%) and no-till + manual slashing (82.44%)

Table 3 Effects of tillage practices on soil chemical properties

Tillage practice	Soil pH (H ₂ O)	Exch. acidity (Cmol/kg)	Org. C (g/kg)	Total N (g/kg)	Av. P (mg/kg)	Ca	Mg	Na	K	CEC	Base sat	Sand (%)	Silt (%)	Clay (%)
<i>Heaping</i>														
(Initial)*	6.8	0.16	7.2	0.76	1.75	0.90	0.20	0.97	0.26	2.54	93.60	90.25	7.20	2.55
(Final)**	6.7	0.10	7.4	0.8	1.60	1.00	0.11	0.91	0.24	2.49	91.71	91.31	7.40	1.29
% Change	1.5	37.50	2.78	14.29	8.57	11.11	45.00	6.19	7.69	1.97	2.02	1.17	2.78	49.40
<i>NTH***</i>														
Initial	6.7	0.16	7.4	0.6	1.74	0.87	0.13	0.94	0.18	2.20	92.95	90.10	7.40	2.50
Final	6.8	0.09	7.9	0.7	1.45	0.95	0.20	0.89	0.20	2.11	94.37	93.11	5.40	1.49
% Change	1.5	43.73	6.76	16.67	16.67	9.20	53.85	5.32	11.11	4.09	1.53	3.23	27.03	40.4
<i>Ridging</i>														
Initial	6.6	0.20	7.7	0.8	1.77	0.91	0.20	0.95	0.31	2.51	90.94	89.80	6.40	3.48
Final	6.7	0.11	7.5	0.7	1.49	0.86	0.16	0.78	0.20	2.14	92.16	91.80	5.40	2.80
% Change	1.5	45.00	2.60	12.5	15.82	5.49	20.00	17.89	35.48	14.74	1.34	2.23	15.63	26.32
<i>NSB***</i>														
Initial	6.8	0.15	7.0	0.6	1.58	0.90	0.23	0.96	0.21	2.17	96.75	89.80	7.40	2.80
Final	6.8	0.09	7.9	71.36	0.92	0.21	0.78	0.16	2.00	92.73	89.80	7.42	2.78	
% Change	0.0	66.67	11.39	14.29	13.92	2.22	8.7	18.75	23.81	7.83	4.16	0.00	0.27	0.71

* Initial - Sampling done immediately after land preparation during the 1994 season

** Final - Sampling done at harvest during the 1995 season

NTH***, No-till + herbicide; NSB***, no-till + slash and burn

treatments. Plant height showed no significant differences at all growth stages (Fig 1). However, average for the two years showed that plants from ridging were taller than other treatments. The above observation could be attributed to adequate and a well distributed rainfall at the planting time in 1994, which ensured adequate soil moisture (Table 2) and reduced the influence of soil bulk density. Similarly, the significant differences observed in sprouting in 1995 is due to differences in soil bulk density at planting (Table 2), coupled with uneven rainfall distribution for the season which probably accentuated the influence of the bulk density. Ndaeyo *et al.* (1995) had observed that with adequate rainfall, crop establishment was very similar on no till and tilled plots while Iwuafor and Kang (1993) noted lower emergence or sprouting under no tillage due to shallow planting depth consequent upon high soil bulk density.

Number of leaves and stem girth: Significant differences ($P < 0.05$) in the number of leaves of cassava were observed from 8 months after planting, with the heaping treatment being higher and no-till + herbicide treatment consistently the lowest (Fig 1). Cassava also indicated no significant differences in stem girth (Fig 1). This could be linked to the influence of optimum soil moisture in all the treatments (Table 2) during most parts of the growing period which probably provided optimum temperature needed for the cassava establishment and growth. These findings conform with those of Alem (1993) who stated that difference in plant growth under different tillage treatments were usually due to a combination of high soil temperature and low soil moisture regimes, as in

dry spells or drought periods.

Cassava yield and yield components: Cassava fresh root yield and yield components (root number per plant, root length and diameter) were not significantly influenced (Table 1) by tillage practices. However, on the average, heaping and ridging indicated some promising fresh root yield results with 18.1 and 14.4; 26.3 and 22.9% in 1994, and 20.8 and 13.0; 29.3 and 22.4% in 1995 over no-till + herbicide and no-till + slash and burn treatments, respectively. This observation could be ascribed to the similarity in the crop establishment and growth performance among the treatments (Fig 1); rainfall, moisture content and bulk density (Table 2) during most parts of the growing periods. These findings confirm the results of those of Ohiri and Ezumah (1999).

Soil moisture content and bulk density: Significant differences in bulk density (Table 4) were observed only at planting. Soil moisture content did not differ significantly throughout the study periods. This could be due to the availability of sufficient soil water throughout the growing periods (Table 2) which apparently prevented one treatment from taking an advantage over the other treatments. Alem (1993) had also reported similar findings.

Soil pH, exchangeable acidity, organic carbon and total nitrogen: Tillage treatments showed no significant effect on soil pH, exchangeable acidity, organic carbon and total nitrogen values (Table 3). However, soil pH value was most stable under no-till + slash and burn. This could be attributed to the alkaline effect of the ash deposited following burning (Ndaeyo *et al.* 1995). Organic carbon declined under ridging

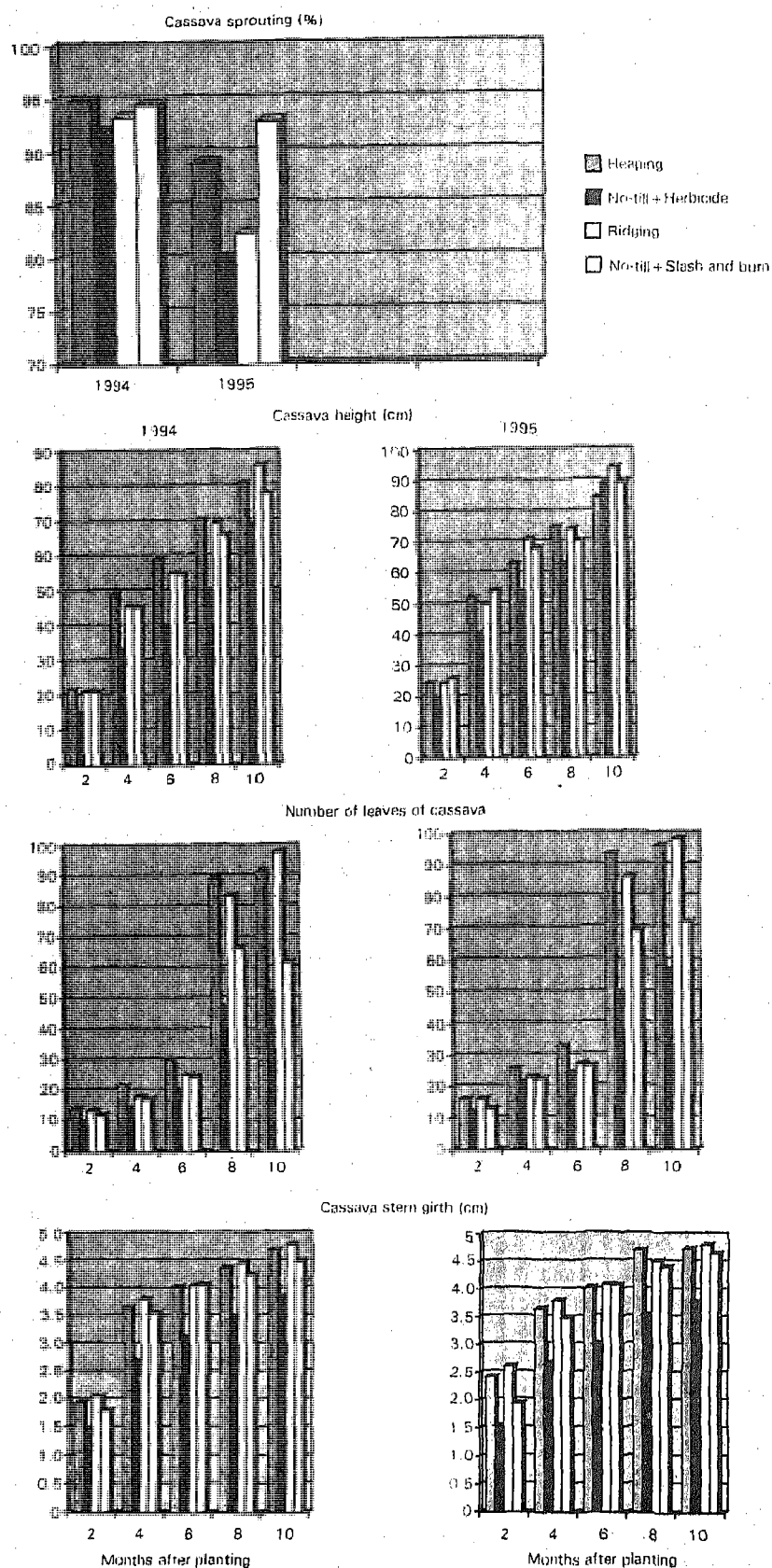


Fig 1 Effect of tillage practices on sprouting, height, number of leaves and stem girth in cassava during 1994 and 1995

Table 4 Cost of production and economic return to management (N/ha) in four tillage practices for cassava production

Farm operation	1994				1995			
	Tillage practice				Tillage practice			
	Heaping	NTH	Ridging	NSB	Heaping	NTH	Ridging	NSB
Production cost (N/ha)								
Land preparation	3500	1400	3000	3000	3500	2000	3600	3000
Weeding	3000	4000	3000	4000	3000	4000	3000	4000
Other costs	2600	2600	26000	2600	2600	2600	2600	2600
Total cost of production	9100	8000	8600	9600	9100	8600	9200	9600
Yield (tonnes/ha)	21.6	17.7	24.0	18.5	23.1	18.3	25.9	20.1
Gross revenue	21600	17700	24000	18500	23100	18300	25900	20100
Return to management	12500	9700	15400	8900	14000	9700	16700	10500
Benefit : Cost ratio	2.4	2.2	2.8	1.9	2.5	2.1	2.8	2.1

* US \$1 = N 80; a - other costs are planting materials and harvesting which were N 600 and N2,000;

b - Yield $\times$ Unit Price of N 1 000 per ton; NTH = no-till + herbicide; NSB = no-till + slash and burn

treatment (2.6%), while no-till + slash and burn showed the highest increase (11.39%) than other treatments. These observations could be ascribed in part to the effect of burning, and perhaps differential rates of leaching and mineralization among the treatments. Dick (1983) had earlier made similar observations. Total nitrogen increased almost uniformly under all the treatments except ridging which declined by 12.5%. This could be linked to leaching particularly as ridging had higher tillage intensity than others. Blevins *et al.* (1983) reported higher concentrations of total nitrogen at surface soil of no-till than tilled plots.

Available P, Ca, Mg, Na, K, cation exchange capacity, base saturation and soil texture: Tillage treatment indicated no significant effect on available P, exchangeable Ca, Mg, Na, K and cation exchange capacity (Table 3). However, available P showed general decrease, ranging from 8.57 to 13.92%, under all the treatments, perhaps due to leaching effect, uptake by the crop and a possible fixation in soil microbial cells (Donahue *et al.* 1990). Calcium increased in all the treatments, ranging from 2.22 to 11.11%, except ridging with a decrease of 5.49%. Magnesium, Na, K and cation exchange capacity exhibited almost a uniform trend with general decrease in all the treatments. The decline could be ascribed to the presence of ash under no-till + slash and burn plot, leaching and perhaps differential rates of solubilization and mineralization among the treatments. There were no significant changes in base saturation, sand, silt and clay contents among tillage treatments (Table 3). However, no-till + slash and burn showed more stable values for the soil texture than other treatments.

Cost of production and economic returns to management: The highest cost of production (Table 4) was observed under no-till + slash and burn plots and the least under no-till + herbicide plots. No-till + slash and burn exceeded heaping, no-till + herbicide and ridging by 5.2, 16.7 and 10.4%, respectively in 1994, and by 5.2, 10.4 and 4.2%, respectively

in 1995. Ridging gave the highest mean benefit-cost ratio of 2.8 (Table 4). The highest cost of production under no-till + slash and burn was probably due to higher costs of labour used for land preparation and weeding operations which accounted for 34.7 and 39.6% of the total cost of production, respectively. Weed infestation was higher (data not shown) on no-till + slash and burn plots than in other treatments. The relatively lower cost of production and higher cassava root yield were accountable for the higher economic return under ridging. The cost of weeding had been to be responsible for a higher cost of production on zero-cultivated plots than cultivated ones (Ndaeyo *et al.* 1995).

Thus, tillage practices have no additional benefits in cassava growth and yield performances. The optimum soil moisture available throughout most parts of the investigations eliminated some stress that could have caused disparity in the crop performance. With the absence of marked effects on cassava yield, it implies that a successful growing of cassava under reduced tillage practices is practicable in this agro-ecological zone. The least decline in soil fertility status under the reduced tillage practice makes it a preferred option, particularly where the cost of labour is low and the needs for water and soil conservation are imperative.

REFERENCES

- Alem G. 1993. Evaluation of tillage practices for soil moisture conservation and maize production in dryland Ethiopia. *Agricultural mechanization in Asia, Africa and Latin America* 24 (3) : 9 - 13.
- Anderson J M and Ingram J S I-1993. *Tropical Soil Biology and Fertility: a Handbook of Methods* 2nd edition. Center for Agricultural and Biostatistics International, Willingford, Oxon, pp 63 - 66
- Blake G R and Hartage K H 1986. Bulk density. (in) *Methods of Soil Analysis*, pp 363-75 Klute A (Ed). Monograph 9, American Society of Agronomy, Madison WI.
- Blevins R L, Thomas G W, Smith M, Frye W W and Cornelius P L

1983. Changes in soil properties after 10 years continuous no till and conventional tilled corn. *Soil Tillage Research* 3 : 135 - 146.
- CIMMYT. 1988. From agronomic data to farmer recommendations: An economic training manual. CIMMYT Mexico, DF CIMMYT, pp 33.
- Dick W A. 1983. Organic carbon, nitrogen and phosphorus concentrations and pH in soil profile as affected by tillage intensity.
- Donahue R L, Miller R W and Shick Luna J C. 1990. Soil: An Introduction to soils and plant growth, pp 421-53, edn 5. prentice Hall-India, New Delhi.
- FAO. 1965. Guidelines for soil description. FAO, Paris. pp 22.
- Ike I F. 1985. Soil and crop responses to different tillage practices in a ferruginous soil in the Nigerian Savanna. *Soil and Tillage Research* 6 : 261 - 72.
- Iwuafor E N O and Kang B T. 1993. Effect of tillage and crop residue management on maize grown on Alfisol in the Savanna cultural zone. *Agric Systems in Africa*. 3 (1) : 71 - 83.
- Ndaeyo N U, Aiyelari E A and Agboola A A. 1995. Evaluation of different tillage practices for monocultural cowpea (*Vigna unguiculata* (L.) Walp) production in Ibadan, south western Nigeria. *African Soils* 28 : 475 - 88.
- Ohiri A C Ezumah H C. 1990. Tillage effects on cassava (*Manihot esculenta*) production and some soil properties. *Soil and Tillage Research* 17 : 221 - 9.
- Smyth A J and Montgomery R F. 1962. Soils of Central Western Nigeria. Government Press, Ibadan, Nigeria, pp 265.
- Zheng Z Lin X Zhang K Ye F and Tran Y. 1992. Recent progress in cassava varietal and agronomic research in China. (in) *Cassava Breeding, Agronomy and Utilization Research in Asia*. Howeler R H (Ed). *Proceedings of 3rd Asian Cassava Workshop*, 22 - 27 October 1990, Malang, Indonesia, pp 64 - 80.

Evaluation of some botanicals against citrus leafminer (*Phyllocnistis citrella*) and psylla (*Diaphorina citri*) on kagzilime (*Citrus aurantifolia*)

P K BORAD¹, M J PATEL², N M VAGHELA³, B H PATEL⁴, M G PATEL⁵, BABUBHAI H PATEL⁶ and J R PATEL⁷

Bansilal Amrutlal College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand 388 110

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ABSTRACT

A evaluation was conducted during 1997-99 at Anand on eight botanicals, viz mint (*Mentha piperita* L.), tulsi (*Ocimum sanctum* L.), ardusi (*Adhatoda vasica* L.), karen (*Nerium indicum* M.), naffatia (*Ipomoea fistulosa* Mart.), neem (*Azadirachta indica* A. Juss.), arni (*Clerodendrum multiflorum* Bur.) and bougainvillea (*Bougainvillea* spp.) were evaluated for their insecticidal property against insect-pests of kagzilime (*Citrus aurantifolia* S.). Spray of neem (*A. indica*) and naffatia (*I. fistulosa*) leaves extracts 10 % suspension effectively managed the population of leafminer, *Phyllocnistis citrella* St and psylla (*Diaphorina citri* K).

Key words : botanicals, citrus, leafminer, psylla

Citrus (*Citrus aurantifolia* S.) is an important fruit crop of Gujarat. Amongst the various insect-pests leafminer, (*Phyllocnistis citrella* St.) and psylla (*Diaphorina citri* K.) are the regularly occurring insect-pests in citrus orchard of middle Gujarat causing considerable loss in yield. Number of plant materials having insecticidal property are available in nature but no information is available for the effective botanicals against citrus pests. Therefore, study was carried out to find out the effective plant materials against these pests.

MATERIALS AND METHODS

The experiment was conducted in completely randomised block design at horticulture farm of the University, Campus Anand with three replications using kagzilime (*Citrus aurantifolia* S.) during 1997-98 and 1998-99. Water extract of leave of eight botanicals, viz mint (*Mentha piperita* L.), tulsi (*Ocimum sanctum* L.), ardusi (*Adhatoda vasica* L.), karen (*Nerium indicum* M.), naffatia (*Ipomoea fistulosa* L.), neem (*Azadirachta indica* A. Jass.), arni (*Clerodendrum multiflorum* Bur.) and bougainvillea (*Bougainvillea* spp), all @ 10% (W/V) were evaluated against citrus leafminer *P. citrella* during kharif season and psylla, *D. citri* during rabi season. The spray fluid was used @ 1 000 litres per hectare with the help of foot sprayer. Larval and nymphal population of leafminer and psylla was recorded, respectively, on randomly selected 10 young twigs (10 cm long) in each treatment prior and after one and two weeks of spray. The trial was conducted in ten years old kagzilime orchard. The

data were subjected to analysis of variance by adopting standard statistical procedure.

RESULTS AND DISCUSSION

The study on bio-efficacy of various plant materials against leafminer infesting kagzilime (Table 1) revealed significant effectiveness of neem leaves 10% suspension (15.00 larvae/10 twigs) against *P. citrella* in comparison to mint, karen, ardusi, arni and bougainvillea (20.84 – 24.50 larvae/10 twigs) after one week of spray. The effectiveness of neem leaves extract suspension in managing the population of *P. citrella* was observed till two weeks after spray and showed significant effectiveness over all the plant materials except naffatia. This may be due to oviposition and feeding deterrent effect of both the extracts. Effectiveness of neem cake extract @ 10% and neem oil @ 1% against *P. citrella* has been reported by Singh and Azam (1986) on citrus and Katole *et al.* (1993) on mandarin, respectively, whereas effectiveness of neem leaf extract @ 10% against maize stem borer has been reported by Bhatnagar and Sharma (1997). Naffatia and tulsi were found equally effective as neem against *P. citrella* after one week of spray but the persistence of tulsi leaves extract suspension could not be found after two weeks of spray and thus, remained significantly less effective than neem and naffatia after two weeks of spray. Tulsi and ardusi leaves extract suspension sprays were found significantly more effective till two weeks after spray than unprotected condition, whereas mint, karen, arni and bougainvillea could not show their significant effectiveness over control after two weeks of spray.

The population of psylla, *D. citri* (Table 2) was found significantly lower (13.17 – 14.50 nymphs/10 twigs) on

¹Associate Professor, ²Senior Research Assistant, ³Assistant Professor, ⁴Associate Research Scientist, ^{5,6}Assistant Research Scientist, ⁷Professor and Head

Table 1 Bio-efficacy of various botanicals against leafminer, *P. citrella* infesting kagzillime

Botanicals*	Average number of leafminers per 10 twigs								
	Before spray			One week			Two weeks		
	1997-98	1998-99	Pooled	1997-98	1998-99	Pooled	1997-98	1998-99	Pooled
Mint	6.45a+ (40.67)	5.94a (35.33)	6.20a (38.00)	4.40bc (19.00)	4.86bc (22.67)	4.63bcd (20.84)	3.46a (11.00)	5.68bc (31.33)	4.57abc (21.17)
Tulsi	6.50a (41.33)	5.92a (34.00)	6.21a (37.67)	3.91bc (14.67)	4.71cd (21.33)	4.31cde (18.00)	3.31a (10.00)	5.71bc (31.67)	4.51bc (20.84)
Ardusi	6.40a (40.00)	5.92a (34.00)	6.16a (37.00)	4.16bc (16.33)	5.49b (29.33)	4.82bc (22.83)	3.56a (11.67)	5.45c (28.67)	4.50bc (20.17)
Karen	6.45a (40.67)	6.11a (36.33)	6.28a (38.50)	4.16bc (16.33)	5.38b (28.00)	4.77bc (22.17)	3.61a (12.00)	6.26ab (38.67)	4.94ab (25.34)
Naffatia	6.56a (42.00)	5.80a (32.67)	6.18a (37.34)	3.45c (11.00)	4.69cd (21.00)	4.07de (16.50)	3.10a (08.67)	5.44c (28.67)	4.27cd (18.67)
Neem	6.52a (41.67)	5.94a (34.33)	6.23a (38.00)	3.84bc (14.00)	4.12d (16.00)	3.98e (15.00)	2.99a (08.00)	4.65d (20.67)	3.82d (14.33)
Arni	6.46a (40.67)	5.91a (34.00)	6.18a (37.34)	4.68ab (21.00)	5.26bc (26.67)	4.97b (23.84)	3.45a (11.00)	6.24ab (38.00)	4.84abc (24.50)
Bougainvillea	6.63a (43.00)	6.14a (36.67)	6.38a (39.84)	4.64ab (20.67)	5.42b (28.33)	5.03b (24.50)	3.41a (11.00)	5.99abc (35.00)	4.70abc (23.00)
Control	6.42a (40.33)	6.07a (36.00)	6.25a (38.15)	5.62a (30.67)	6.19a (37.33)	5.90a (34.00)	3.67a (12.67)	6.53a (41.67)	5.10a (27.17)
SEm ±	0.19	0.13	0.11	0.31	0.19	0.18	0.22	0.22	0.17
CV (%)	5.05	3.63	4.46	12.27	6.28	9.29	11.26	6.70	8.39

* Leaves extract at 10% concentration $\sqrt{x+1}$ transformed values

Figures in parentheses are original values

Table 2 Bio-efficacy of various botanicals against psylla *D. citri* infesting kagzillime

Botanicals*	Average numbers of leafminers per 10 twigs								
	Before spray			One week			Two weeks		
	1997-98	1998-99	Pooled	1997-98	1998-99	Pooled	1997-98	1998-99	Pooled
Mint	6.07a+ (36.00)	9.10a (82.00)	7.59a (59.00)	4.38b (18.33)	4.75de (21.67)	4.57bcd (20.00)	3.21b (09.23)	5.34ab (27.67)	4.27b (18.50)
Tulsi	6.07a (36.00)	8.89a (78.33)	7.48a (57.17)	4.19bc (16.67)	4.58e (20.00)	4.39cd (18.34)	3.20b (09.33)	5.13b (25.33)	4.17b (17.33)
Ardusi	6.05a (36.00)	8.99a (80.00)	7.52a (58.00)	4.79b (22.00)	5.58cd (30.67)	5.19bc (26.34)	3.50ab (11.33)	5.41ab (28.33)	4.46b (19.83)
Karen	5.86a (33.33)	9.39a (87.33)	7.62a (60.33)	4.79b (22.00)	5.70bc (31.67)	5.25bc (26.84)	3.51ab (11.33)	5.34ab (27.67)	4.43b (19.50)
Naffatia	6.01a (35.33)	9.14a (82.67)	7.57a (59.00)	3.73cd (13.00)	4.12e (16.00)	3.92d (14.50)	3.30ab (10.00)	5.22ab (26.67)	4.26b (18.34)
Neem	5.91a (34.33)	9.30a (85.67)	7.61a (60.00)	3.55d (11.67)	3.94e (14.67)	3.75d (13.17)	3.10b (8.67)	5.28ab (27.00)	4.19b (17.84)
Arni	5.79a (32.67)	9.25a (84.67)	7.52a (58.67)	4.65b (20.67)	5.58cd (30.33)	5.11bc (25.50)	3.50ab (11.33)	5.60ab (30.67)	5.55ab (21.00)
Bougainvillea	5.86 (33.67)	9.02a (80.67)	7.47a (57.17)	4.76b (21.67)	6.60b (42.67)	5.68ab (32.17)	3.44ab (11.00)	5.35ab (27.67)	4.39b (19.34)
Control	6.12a (37.67)	9.31a (86.33)	7.72a (62.00)	5.65a (31.00)	7.95a (62.33)	6.80a (46.67)	6.26a (13.67)	6.26a (38.33)	5.04a (23.67)
SEm ±	0.34	0.33	0.22	0.18	0.28	0.35	0.17	0.33	0.17
CV (%)	9.76	6.23	7.63	6.84	8.81	8.10	8.88	10.52	10.35

* Leaves extract at 10% concentration $\sqrt{x+1}$ transformed values

Figures in parentheses are original values

kagzilime trees sprayed with neem and naffatia leaves extract suspension after one week of spray in comparison to rest of the plant materials (20.00 – 32.17 nymphs/10 twigs) except tulsi leaves extract suspension (18.34 nymphs/10 twigs). Effectiveness of neem @ 5% against citrus blackfly and neem leaf extract @ 3% against *Myzus persicae* Sulzer has been reported by Kuchanwar *et al.* (1993) and Parihar *et al.* (1999) respectively. Bougainvillea leaves extract suspension sprayed trees had significantly higher psylla population than tulsi leaves extract suspension sprayed trees. Mint, tulsi, ardusi, karen and arni were found equally effective against *D. citri* after one week of spray and showed significant superiority to control and maintained their effectiveness against psylla even after two weeks of spray except arni.

Thus, neem and naffatia leaves extract 10% suspension spray effectively managed the population build up of *P. citrella* and *D. citri* in kagzilime orchard of middle Gujarat.

REFERENCES

- Bhatnagar, Anuj and Sharma V K. 1997. Effects of neem leaf and custard apple seed extracts on maize stemborer, *Chilo partellus* (Swinhoe). *Plant Protection Bulletin* 19 (1/4) : 33-40.
- Katole S R, Thakure H S and Maheyani R K. 1993. Effects of some plant products and insecticides on the infestation of citrus leafminer on Nagpur mandarin. *Journal of Maharashtra Agricultural University* 18 (1) : 67-8.
- Kuchanwar DB, Hardas M G and Kunte Y N. 1993. Efficacy of some botanical insecticides compared with conventional insecticides in the control of citrus blackfly. *Pestology* 17 (2) : 29.
- Parihar S B S, Thapaliyal P and Ramkishore. 1999. Effect of botanicals against peach aphid, *Myzus persicae* (Sulzer). *Insect Environment* 5 (2) : 84.
- Singh T V K and Azam K M. 1986. Seasonal occurrence, population dynamics and chemical control of citrus leafminer, *Phyllocnistis citrella* Stainton in Andhra Pradesh. *Indian Journal of Entomology* 48 (1) : 38-42.

Effectiveness of *Dennettia tripetala* and *Eugenia aromatica* on stored cowpea (*Vigna unguiculata*) seed against infestation by *Callosobruchus maculatus*

O A LAWAL¹

Ogun State University, Ago-Iwoye, Ogun State, Nigeria

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ABSTRACT

An experiment was conducted to study the efficacy of 3 application rates of dry powders of *Dennettia tripetala* and *Eugenia aromatica* for the control of *Callosobruchus maculatus* (Fab.). The various doses of dry powder @ 2.5, 5.0 and 7.5/250 g fruit) were found effective in reducing oviposition and damage to seeds of cowpea (*Vigna unguiculata* (L.) Walp.). *Eugenia aromatica* was found the most effective in discouraging oviposition and minimizing the damage to the seeds of cowpea, as indicated by the significantly lower number of emergence holes on the seeds. The dry powders of *D. tripetala* and *E. aromatica* did not affect seed viability and quality.

Key words: crop productivity, nutrient uptake, soil fertility, cropping system, fertilizers, pigeonpea-wheat

The main cowpea-producing territories of Africa fall within the drier areas of the West African Savanna Zone; appreciable quantities are also grown in some East African countries, where the tender leaves are also used as vegetable (Kayumbo 1975). Cowpea is one of the most important leguminous crops in sub-Saharan Africa (Ng and Marechal 1985).

Among the post-flowering pests, the cowpea seed beetle *Callosobruchus maculatus* Fab. is a serious insect pest of cowpea. Infestation begins in the field, but serious damage is done on pods and/or seeds during storage (Warni 1984). The major factor responsible for serious loss of cowpea in store is the result of serious infestation from *C. maculatus*. No good storage facilities and high cost of synthetic pesticides coupled with the potential hazard posed problems to the environment, humans, and livestock. This necessitated the search for various local plant products for use in the control of insect pest of cowpea in storage (Ajayi *et al.* 1987, and Dike *et al.* 1992). Nigerian farmers utilize local plant products to control insect pests in stored produce. This study reports the results of using three application rates of dry powders of *Dennettia tripetala* and *Eugenia aromatica* for the control of *C. maculatus* in stored cowpea.

MATERIALS AND METHODS

Dennettia tripetala belongs to the family Anonaceae and *Eugenia aromatica* belongs to the family Myrtaceae. They are perennial plants found in tropical and sub-tropical zones.

The fruits of the two plants were bought from a local market. They were washed in sterile distilled water and dried in the oven at 60°C for 72 hr and ground to a fine powder (Langenean 1948). The dry powders from both fruits were weighed into three lots of 2.5 g, 5.0 g and 7.5 g using a Mettler weighing balance.

The cowpea was bought from local market. The cowpea was put in a deep freezer for two weeks to destroy micro-organisms and to get rid of infestation of insects according to Metcalf *et al.* (1975).

A culture of cowpea and *C. maculatus* was set up at laboratory temperature for 3 weeks to breed sufficient numbers of the insects for use in the experiment. From the preserved cowpea, 250 g of seeds were weighed and placed in kilner jars. The dry powders from both fruits corresponding to 2.5 g per 250 g, 5.0 g per 250 g and 7.5 g per 250 g were kept/placed in each kilner jar and shaken gently for about five minutes to ensure thorough admixture.

The test insects were 10 pairs obtained from laboratory culture were introduced into each of the kilner jars of each replicate.

The jars were covered with a fine muslin cloth to enable aeration of the jar contents. The experiment consisting of eighteen treatments plus control of three replicates in each experiment which was set up under laboratory conditions of temperature 28°C ± 2°C and 67.5% ± 7.5% relative humidity.

At 4 and 8 weeks of the treatment the number of eggs deposited on a random sample of 40 grains, Mortality rate, number of emergence holes of *C. maculatus* and germination test was done on 40 g of cowpea seeds randomly selected.

¹Lecturer, Department of Biological Sciences

Table 1 Mean numbr of egg per 40 cowpea seeds

Treatment	Concentration (g)					
	2.5 g/250 g seed		5.0 g/250 g seed		7.5 g/250 g seed	
	4 weeks	8 weeks	4 weeks	8 weeks	4 weeks	8 weeks
<i>E. aromatica</i>						
<i>D. tripetala</i>	0.20	0.32	0.13	0.55	0.03	0.08
Untreated	2.12	2.40	1.65	1.90	0.87	1.00
LSD	12.00	30.1	15.0	28.4	13.5	29.0
	2.68**	5.27**	7.68**	5.52**	6.66**	6.49**
<i>Number of dead insect</i>						
<i>E. aromatica</i>	44.4 ^c	49.2 ^{ah}	56.2 ^{ch}	60.1 ^{ch}	66.9 ^{ch}	74.2 ^{ha}
<i>D. tripetala</i>	18.4 ^h	20.9 ^h	36.4 ^{hc}	39.2 ^{hc}	52.3 ^{cd}	56.1 ^{cd}
Untreated	2.45 ^a	3.46 ^a	4.45 ^a	5.34 ^a	4.65 ^a	8.72 ^a
<i>Number emergence hole/40 cowpea seeds</i>						
<i>E. aromatica</i>	2.21	2.25	1.78	1.86	1.20	1.25
<i>D. tripetala</i>	2.94	3.11	1.91	2.01	1.45	1.63
Untreated	17.50	18.5	17.00	17.00	21.90	22.10
LSD	2.93**	3.02**	4.74**	4.92**	4.56**	4.66**

from the bulked seeds from the 3 replicates. The 40 g of cowpea seeds were laid on moist filter paper in glass petri-dished which were exposed to sunlight. The germination counts were assessed after (4 days) four days.

The data obtained were subjected to analysis of variance method and the means were separated according to Duncan's multiple range test (Peterson 1985).

RESULTS AND DISCUSSION

Mean number of eggs found on the cowpea seeds treated with 2.5 g, 5.0 g and 7.5 g of both *E. aromatica* and *D. tripetala* for four weeks and eight week and show (Table 1). It was evident from the data that at every rate of treatment there is a discouragement of oviposition by *C. maculatus* which was significant at $P \leq 0.05$ at both four weeks and eight weeks.

E. aromatica was the most effective by revealing low number of eggs laid by *C. maculatus*. A every rate of treatment *E. aromatica* recorded the highest rate of mortality while *D. tripetala* shows a level mortality rate that is higher than the control. There was a significant difference at $P \leq 0.05$ in the mortality rate.

The number of emergence hole on cowpea seed as a result of effect of the fruit powder on the pests which was very significant at $P \leq 0.05$ in protecting the cowpea seed from being damage by *C. maculatus*.

The germination percentage the viability of the cowpea seed was not affected by the application of the fruits powder. The rate of germination ranging from 95.9 – 100% of cowpea seed exposed to the fruit powder treatment at the three different levels of application.

The results revealed that the powders (*E. aromatica* and *D. tripetala*) highly reduced the damage done to cowpea

seed by *C. maculatus*. This is in agreement with the finding of Hassanali *et al.* (1990) that use of *E. caryophyllata* as grains protectant in part of East Africa. Iwuala (1981) reported the insecticidal property of *D. tripetala* on the adult and nymph of *Periplanetta americana* and *Zonocerus variegatus*. As the doses increased the effectiveness of the powder on *C. maculatus* also.

The powders did not affect the viability of the treated seeds. This can be of great use to farmers storing cowpea or stored products/grains. Moreover being a natural product and consumable to man with no apparent ill effect, they could become a cheap means of effective control of damage done to stored cowpea/grains by *C. maculatus*.

REFERENCES

- Ajayi O, Arokoyo J T, Nezan J T, Olayinka B M, Ndirinbula B M and Kanneke O A. 1987. Laboratory assessment of the efficacy of some local plant materials for the control of storage insect pests. *Samaru Journal of Agricultural Research* 5 : 81–6.
- Dike M C and Mbatt O I. 1992. Evaluation of lemon grass (*Cymbopogon citrates* Staph). Products in the control of *Callosobruchus maculatus* F. on stored cowpea. *Nigeria Journal for Plant Protection* 14 : 88–91.
- Hassanali A W, Lwande N, Lmoreka S, Noyala, Sitoyo and Chappa A. 1990. Weevil repellent constituents of *Ocimum sware* leaves and *Eugenia caryophyllata* used as grains protectants in part of Eastern Africa. *Discovery and Innovation* 2 (2) : 91–5.
- Iwuala, M O E. 1981. Denettia oil a potential new insecticides test with adult and nymph to *Periplanetta americana* and *Z. variegatus*. *Journal of Economy Entomology* 74 (31) : 249–52.
- Kayumbo H Y. 1975. Crop protection in mixed ecosystem. Paper-presented at the symposium on intercropping in semi-arid areas.

- Morogora, Tanzania, 10-12 May 1975.
- Metalf R L and Luckman W. 1975. *Introduction to Pest Management*. John Willey and Sons, New York.
- Ng N W and Marechal R. 1985. Cowpea taxonomy, origin and germplasm. (in) *Cowpea Research, Production and Utilization* Sign S R and Rachie K O Chichester (Eds). John Willey and Sons Ltd. Chuchester, 11-21.
- Peterson R G. 1985. *Design and Analysis of Experiment*. McGraw Hill, Chuchester.
- Warni M. 1984. Bruchid infestation of cowpea varieties in the field. *Insect Science Application* 5 : 283-6.

Effect of planting material, plant population and organic manures on growth components and yield of galangal (*Kaempferia galanga*) when grown as intercrop in coconut garden*

H P MAHESWARAPPA¹, H V NANJAPPA² and M R HEGDE³

Central Plantation Crops Research Institute, Kasaragod, Kerala 671 124

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Key words: *Kaempferia galanga*, intercrop, coconut, organic manures, growth characters, yield

Due to increased health consciousness of the people in general and carcinogenic hazards of the synthetic drugs, there is enhanced demand for the products of medicinal plants. However, as their availability from natural resources is limited, there is need to find a place for these crops in our existing cropping system and also workout appropriate agro-techniques. The scope for increasing the land area under cultivation being negligible, intensive cultivation of crops and raising the productivity per unit area is the only means of increasing food production. In case of coconut which remains committed to the land for decades with long gestation period, it is advisable to practice inter/mixed cropping for getting additional and staggered income. Studies on land and solar energy utilization in coconut garden revealed the amenability of the palm in intensive cropping to harness the unutilised space, solar energy and other resources.

Galangal (*Kaempferia galanga* L.) is an important medicinal-cum-aromatic herbaceous stemless plant belonging to Zingiberaceae family. The rhizomes of this crop are the economic part, and are used in ayurvedic medicine as stimulant, diuretic, stomachic, carminative and also used as flavouring agent, etc. The rhizomes on distillation yield an essential oil, which finds use in perfumery and curry flavourings. In addition to essential oil, the rhizomes also yield oleoresin. Oleoresin is the total flavour extract comprising of essential oil, non-essential oil, pungent principles, colours and fats. This crop comes up very well under shaded condition. The information on effect of planting material, plant population and organic manures on growth of galangal when grown as intercrop in coconut garden is meagre. Hence, a study was conducted at Kasaragod during

1995-98 to study the effect of agronomic practices on growth and yield of galangal.

Field experiments were conducted during 1995 - 98 at the Institute, Kasaragod which is situated at 12°30' N latitude and 75° 00' E longitude at an elevation of 10.7 m above mean sea-level. The soil was red sandy loam with the field capacity of 7.40 and 8.95 % at 0-25 and 25-50 cm respectively. The soil was low in available N, and K and was high in available P. The field experiment was laid out in a split plot design with three replications. Types of planting material and population levels formed the main plot treatments, viz mother rhizome with 333 thousands population/ha (20 cm x 15 cm spacing) (S_1P_1), and 500 thousands population/ha (20 cm x 10 cm spacing) (S_1P_2), finger rhizome with 333 thousands population/ha (S_2P_1) and 500 thousands population/ha (S_2P_2). Organic manures like farmyard manure : 24 tonnes/ha (F_1), farmyard manure : 32 tonnes/ha (F_2), composted coir pith : 29 tonnes/ha (F_3), composted coir pith : 39 tonnes/ha (F_4), vermicompost (VC) : 21 tonnes/ha (F_5), vermicompost : 28 tonnes/ha (F_6), farmyard manure (20 tonnes/ha) + NPK (50:50:50 kg/ha) (F_7), NPK alone (50:50:50 kg/ha) (F_8) (KAU, Trissur 1991) and control (F_9) formed the subplot treatments. The raised beds of 2 m x 1.8 m size were prepared in between coconut rows by leaving 2 m radius from the bole of the coconut, aged 35 years old and spaced at 7.5 m x 7.5 m. The rhizomes were planted on a raised bed during first week of June (during 1995-96), second week of May (during 1996-97) and third week of May (during 1997-98) and harvested during first week of February (during 1995-96), third week of January (during 1996-97) and fourth week of January (during 1997-98). The intercrop was irrigated during November till the harvest. Duration of the crop was 8 months. The same treatments were superimposed in the same plot during the second and third year.

Observation on growth characters were carried out from labelled plants. The leaf area (LA) cm²/plant, leaf area index and leaf area duration (LAD) (days) (Watson 1952) were calculated using the following formula;

Length x breadth method was used Leaf factor for

*Short note

Based on a part of the PhD thesis submitted by the first author to the UAS, Bangalore during 1997

¹ Senior Scientist (Agronomy) CPCRI, R S Kayangulam, Kerala 690 533; ² Professor of Agronomy, UAS, Bangalore 560 065;

³ Senior Scientist (Agronomy), TOT, Zonal Co-ordinating unit, Adugodi, Bangalore 560 030

Table 1 Sprouting (%), number of tillers/plant and number of leaves/plant as influenced by different treatments in galangal*

Treatment	Sprouting 30 days after planting	No. of tillers		No. of leaves		Leaf area		LAD			Yield
		60 days after planting	180 days after planting	60 days after planting	180 days after planting	60 DAP	120 DAP	180 DAP	60-120 DAP	120-180 DAP	
<i>Planting material</i>											
S1 (Mother rhizome)	88.2	2.2	3.5	4.4	11.0	141.4	243.6	377.6	47.9	79.9	4.8
S2 (Finger rhizome)	88.4	2.2	3.4	4.4	10.7	135.1	226.1	340.8	44.8	69.8	4.7
'F' test	NS	NS		NS							
SEm±	0.06	0.08	0.02	0.09	0.08	0.73	0.75	1.99	0.32	0.72	0.02
CD (P=0.05)			0.06		0.28	2.54	2.60	7.89	0.45	1.02	0.07
<i>Plant population levels</i>											
P1: 333 thousands/ha (20×15 cm)	88.2	2.2	3.6	4.4	11.4	138.2	246.7	381.8	38.5	62.9	4.5
P2: 500 thousands/ha (20×10 cm)	88.3	2.3	3.4	4.4	10.3	138.3	222.0	336.5	54.1	83.8	4.8
'F' test	NS	NS		NS		NS					
Sem±	0.06	0.08	0.02	0.09	0.08	-0.73	0.75	1.99	0.32	0.72	0.02
CD (P=0.05)			0.06		0.28		2.60	6.89	0.45	1.02	0.07
<i>C Organic manures and levels</i>											
F ₁ : FYM: 24 tonnes/ha	88.4	2.5	3.8	4.8	11.7	160.7	303.4	392.0	57.7	86.1	5.2
F ₂ : FYM: 32 tonnes/ha	88.2	2.4	3.8	4.8	11.5	158.5	294.5	375.8	53.9	80.7	5.2
F ₃ : CCP: 29 tonnes/ha	87.9	2.1	3.2	3.8	9.3	107.2	158.6	266.5	32.7	52.4	3.4
F ₄ : CCP: 39 tonnes/ha	88.6	2.0	3.1	3.8	9.0	113.8	152.7	267.1	33.0	50.9	3.4
F ₅ : VC: 21 tonnes/ha	88.3	2.3	3.7	5.0	11.3	159.6	293.2	402.5	55.6	85.9	5.2
F ₆ : VC: 28 tonnes/ha	88.3	2.4	3.8	5.0	12.4	160.2	289.2	472.2	55.7	94.0	5.3
F ₇ : FYM(20t/ha)+NPK (50:50:50kg/ha)	88.2	2.4	3.9	5.0	12.2	159.6	300.6	439.3	57.3	91.6	6.0
F ₈ : NPK(50:50:50kg/ha)	88.2	2.3	3.5	4.4	11.2	127.2	196.7	401.8	40.6	73.8	4.6
F ₉ : Control	88.2	1.8	2.9	3.0	8.8	102.4	138.7	260.1	30.0	44.6	2.5
'F' test	NS										
SEm±	0.13	0.05	0.03	0.05	0.11	1.11	0.93	1.85	0.18	0.26	0.03
CD (P=0.05)		0.15	0.11	0.14	0.32	3.16	2.65	5.23	0.51	0.73	0.09

FYM, Farmyard manure; CCP, composted coirwith; VC, vermicompost

$$\text{kacholam} = 0.628 \text{ LAD} = L(i) + L(i+1) / 2 \times t_2 - t_1$$

L (i)= Leaf area index at ith stage

L (i+1)= Leaf area index at (i+1)th stage

 $t_2 - t_1$ = Time interval between ith and (i+1)th stage in days

Sprouting

Sprouting was not influenced by the types of planting material or plant population levels and different organic manures. The overall sprouting % ranged between 88.0 and 88.7 % (Table 1). Since both mother rhizome and finger rhizome have sufficient reserve food material, the sprouting was similar in both the types of planting material.

Number of tillers, number of Leaves and leaf area

Number of tillers, number of leaves and leaf area produced with mother rhizome were significantly more at 120 and 180 days after planting (Table 12) compared to finger rhizome, whereas above growth components were on a par with mother rhizome and finger rhizome at 60 days after planting. The mother rhizome, which is heavier than finger

rhizome produced vigorous plants compared to finger rhizome. Rajagopalan and Gopalakrishnan (1985) also reported the vigorous growth of galangal (kacholam) with mother rhizome compared to finger rhizome.

Plant population levels did not show any significant difference with respect to number of tillers, number of leaves during 60 and 120 days after planting, whereas plant population at 333 thousands/ha gave more number of tillers, more number of leaves at 180 days after planting compared to 500 thousands/ha population level. Leaf area observed with 333 thousands/ha population was significantly superior at 120 and 180 days after planting, compared to 500 thousands/ha population level. The growth of galangal is very slow up to 120 days after planting, thereafter it picks up its growth. From 120 days after planting, due to faster growth, the higher plant population resulted in competition within the plant community resulting in lower leaf area per plant. Among organic manures, farmyard manure+NPK, farmyard manure and vermicompost at both the levels had higher number of tillers, number of leaves and leaf area at all the

Table 2 Interaction effects of S×P×F on number of tillers, leaf area (cm²/plant), leaf area duration (days) of galangal *

Treatment	F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇	F ₈	F ₉
S ₁ P ₁	4.1	4.1	3.1	3.1	4.2	4.1	4.2	3.8	2.8
S ₁ P ₂	3.7	3.8	3.1	3.1	3.6	3.8	3.8	3.4	2.8
S ₂ P ₁	3.7	3.7	3.1	3.1	3.8	3.8	4.0	3.3	2.8
S ₂ P ₂	3.7	3.7	3.1	3.1	3.6	3.6	3.8	3.3	2.8
CD (P=0.05) for F at the same levels of S×P = 0.20									
CD (P=0.05) for S × P at the same or different levels of, F= 0.21									
<i>Leaf area (cm²/plant) at 180 days after planting*</i>									
S ₁ P ₁	425.0	402.3	282.6	287.9	442.5	517.6	491.8	462.3	241.7
S ₁ P ₂	388.1	380.1	270.4	230.9	427.4	490.9	422.5	418.9	207.6
S ₂ P ₁	406.8	381.7	274.0	288.5	403.7	482.3	440.3	417.6	214.7
S ₂ P ₂	345.2	333.0	239.1	243.1	336.2	397.1	401.5	305.4	213.5
CD (P=0.05) for F at the same levels of S×P =10.45									
CD (P=0.05) for S × P at the same or different levels of F= 13.79									
<i>Leaf area duration (days) during 120-180 days after planting*</i>									
S ₁ P ₁	74.5	71.8	46.1	45.6	76.1	83.1	80.9	66.6	39.2
S ₁ P ₂	102.0	100.2	63.3	58.3	108.3	116.7	108.5	92.1	51.8
S ₂ P ₁	71.4	67.7	44.6	45.0	70.5	78.1	73.9	60.9	35.4
S ₂ P ₂	86.3	83.2	55.7	55.0	88.7	98.1	103.2	75.7	52.2
CD (P=0.05) for F at the same levels of S×P = 1.47									
CD (P=0.05) for S × P at the same or different levels of F= 2.0									

S: Sizes of planting material P : population levels, F: organic manures

observed growth stages compared to composted coir pith at both the levels, NPK alone and control. Better growth under these treatments was also attributed to better availability of nutrients.

Interaction effects of all the factors studied were significant at 180 days after planting for all the growth parameters (Table 2). Mother rhizome with 333 thousands/ha population plus F₇, farmyard manure at both the levels and vermicompost at both the levels produced significantly higher number of tillers, leaf area compared to other combinations.

Leaf area duration

Leaf area duration was significantly superior under mother rhizome treatment compared to finger rhizome at all the growth stages (Table 1). Higher leaf area duration under mother rhizome was mainly due to vigorous growth, production of more number of leaves (11 leaves/plant) and higher leaf area (377.6 cm²/plant). Plant population level of 500 thousands/ha had higher leaf area duration compared to 333 thousands/ ha population level. At higher population level, the leaf area produced for the given area was higher due to narrow spacing provided within the rows (20 cm × 10 cm) resulting in higher leaf area duration compared to lower plant population level which has wider spacing within the rows (20 cm × 15 cm).

Among organic manures, farmyard manure+NPK, farmyard manure and vermicompost at both the levels recorded significantly higher leaf area duration at all the growth stages. This was mainly attributed to higher leaf area produced under these treatments and maintenance of

functional leaves till the attainment of physiological maturity period.

Interaction effect of mother rhizome with 500 thousands per ha plus F₇, farmyard manure and vermicompost at both the levels showed significantly higher leaf area duration (Table 2) compared to other combinations.

Fresh rhizome yield

Pooled data of fresh rhizome yield under mother rhizome (4.8 tonnes/ha) was significantly higher compared to finger rhizome (4.7 tonnes/ha) (Table 1). The per cent reduction in the yield under finger rhizome treatment was only 2.1 per cent compared to mother rhizome. Similar results of superior yield with mother rhizome in galangal has been reported by Rajagopalan and Gopalakrishnan (1985). In taro, Mohankumar and Sadanandan (1988) reported the similar yields by planting side corms (cormel) or mother corms.

The fresh rhizome yield was significantly higher at 500 000 / ha population level (4.8 tonnes/ha) compared to 333 000 / ha population level (4.5 tonnes/ha). The per cent reduction in yield due to lower density population was 6.7 %. The increase in yield under higher population was attributed to more population per hectare. Eventhough the growth components were superior with 333 000/ha population level, as the yield components were only on par at both the levels of population, the 333 000 / ha population level could not compensate the total yield that was realised in 500 000/ha population level. Randhawa *et al.* (1972) reported that the yield obtained under spacing of 20 cm × 20 cm or 20 cm × 30 cm was found to be optimum compared to

lesser or wider spacing in ginger. Singh and Neopaney (1993) also reported that closer spacing was found to be optimum for getting maximum yield in ginger compared to wider spacing.

Fresh rhizome yield obtained was significantly superior with farmyard manure+NPK (6.0 tonnes/ha) compared to other treatments. Combination of organic manure with chemical fertilizer resulted in better growth of the crop as reflected in more number of leaves, tillers, higher leaf area duration and yield components. Farmyard manure and vermicompost at both the levels also recorded significantly higher yield compared to composted coir pith at both the levels, NPK alone and control. NPK alone recorded significantly higher yield compared to composted coir pith at both the levels.

REFERENCES

- KAU, Trissur. 1991. *Research Report*. Kerala Agricultural University, Vellanikara, Trissur.
- Mohankumar, C R and Sadananda N N. 1988. Effect of sources of planting material and mulching on the growth and yield of taro. *Journal of Root Crops* 14 (2):55-7.
- Rajagopalan A and Gopalakrishnan P K. 1985. Growth, yield and quality of *Kaempferia galanga* L. as influenced by planting time and type of seed material. *Agricultural Research Journal of Kerala* 23 (1) : 83-9.
- Randhawa K S, Nandpuri K S and Bajwa M S. 1972. Studies on the comparative efficacy of different sizes of seed and spacings on the yield of ginger (*Zingiber officinale* Rosc). *Journal of Research, PAU* 9 (2) : 239-44.
- Singh A K and Neopaney B. 1993. Effect of NPK nutrition and spacing on yield attributes in ginger. *Haryana Journal of Horticultural Science* 22 (2) : 143-8.
- Watson D J. 1952. The physiological basis of variation in yield. *Advances in Agronomy* 4 : 101-45.

Performance of urea super granule and prilled urea under different planting methods in irrigated rice (*Oryza sativa*)

V P JAISWAL¹ and G R SINGH²

Narendra Deva University of Agriculture and Technology, Faizabad, Uttar Pradesh 224229

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Key words: rice, urea super granule, prilled urea, planting methods, nitrogen levels, nitrogen-use efficiency

Nitrogen is a major input for higher productivity of rice. In lowland situation N-use efficiency has been estimated to be about 30–50% and in many cases even less (Sarvanan *et al.* 1988). Low recovery of applied nitrogen by the crop has been attributed to losses through denitrification, ammonia volatilization, runoff and immobilization. In case it becomes possible to increase the N-use efficiency to level of more than 50% by resorting to deep placement of nitrogen as modified urea materials, it would not only but also towards improving the nitrogen use efficiency at farm level and consequent improvement in rice production. The low nitrogen efficiency has attracted the attention to devise better management practices although efforts have been made but significant impact is yet to be ascertained in transplanted rice only. The present investigation was therefore, undertaken to assess comparative efficiency of urea super granule and prilled urea on growth, N-uptake and yield of rice under different planting methods.

A field experiment was conducted for 2 seasons (1996–97 and 1997–98) at the Agronomy farm of the University.

The soil was silty loam in texture with pH, 7.8; low organic carbon (0.32%); available nitrogen 200 kg/ha; available phosphorus 16.0 kg/ha and available potash 257.0 kg/ha. The treatments were arranged in split plot design, keeping three planting methods, viz transplanting, broadcasting of sprouted seed under puddled conditions and direct seeding in main plots, combination of two sources (urea super granule and prilled urea) with two nitrogen levels (60 and 120 kg/ha) along with control (0 kg/ha) in sub-plots with four replications. Full dose of P (26.2 kg/ha), K (50 kg/ha) and 25 kg zinc sulphate were applied as basal application before direct seeding/broadcasting under as well as transplanting conditions. Nitrogen through prilled urea was applied in three splits, ie 1/3 as basal, 1/3 at tillering

and rest 1/3 at the time of panicle initiation. Nitrogen through urea super granule were applied as total in point placement method by placing each ball of 1 g through applicator in the centre each among four hills at 5 cm depth 8 days after transplanting. In direct seeding methods, dry seeds were sown in rows at 20 cm apart @ 100 kg/ha. Sprouted seeds (@ 100 kg/ha) were broadcasted uniformly under puddled conditions. For transplanting the nursery was raised by sowing the sprouted seeds @ 40 kg/ha and 20-day old seedlings were transplanted at the spacing of 20 cm×10 cm using two seedlings/hill. Plant samples were collected from each plot at different stages of crop growth, ie 60, 80, 100 and 120 days after sowing. Plant samples were analysed for nitrogen content by kjeldahl method.

Transplanting method recorded significantly higher values of panicles/m², grains/panicle and panicles length resulted higher grain yield of 4.53 tonnes/ha, which was 8.9 and 16.4% higher than those obtained under broadcasting of sprouted seed in puddled condition and direct seeding method, respectively. The higher yield under transplanting method was due to better performance of growth and yield attributes through optimum utilization of growth resources which had direct bearing on the production of higher grain yield. The lowest grain yield was recorded under direct seeding because of lesser number of effective tillers/m². The significantly maximum number of shoots/m² was recorded under broadcasting of sprouted seeds followed by direct seeding and transplanting at all the stages of crop growth (data not reported). High density in broadcasting and direct seeding methods increased the inter and intra plant competition for available resources. These findings are also well supported by Singh *et al.* (1997).

Urea super granule significantly recorded higher number of panicles/m², filled grains/panicle, test weight, grain and straw yield of rice. Deep placement of urea super granule was possibly due to adequate nutrient supply with minimizing losses of nitrogen. NH₃ volatilization, nitrification and denitrification which ultimately increased the yield attributing characters resulting in higher yields. Similar observations were also reported by Saha and Mitra

Based on a part of Ph D thesis submitted by the author to the N D U A T, Faizabad

¹Scientist (Senior Scale), Indian Institute of Sugarcane Research Lucknow 226 002

²Professor, Division of Agronomy

Table 1 Yield and yield components of rice as affected by planting method nitrogen source and level (mean of 1996-97 and 1997-98)

Treatments	Panicles/ m ²	Filled grains/ panicle	Panicle length (cm)	1 000- grain weight (g)	Straw yield (tonnes)	Grain yield (tonnes)	Harvest index (%)
<i>Planting method</i>							
Transplanting	280.5	128.8	21.97	22.33	60.12	4.53	42.06
Broadcasting	262.1	122.3	21.48	22.52	5.90	4.16	41.11
Direct seeding	242.1	111.5	21.34	22.91	5.59	3.89	40.78
LSD ($P=0.05$)	4.84	2.28	0.47	NS	2.14	1.13	
<i>Nitrogen source</i>							
Prilled urea	269.5	124.0	22.01	22.82	6.24	4.44	41.51
Urea super granule	283.9	133.0	22.32	23.18	6.74	4.93	42.21
LSD ($P=0.05$)	3.02	2.53	NS	0.25	2.05	0.975	
<i>Nitrogen level</i>							
0*	201.3	90.7	19.31	20.85	34.77	2.23	39.12
60	254.8	119.9	21.85	22.76	58.64	4.13	41.34
120	298.6	136.9	22.48	23.24	71.26	5.24	42.38
LSD ($P=0.05$)	3.02	2.53	0.35	0.25	2.05	0.975	

*Control versus treatment - significant

(1988). Application of nitrogen at 120 kg/ha gave maximum grain yield of 5.24 tonnes/ha which was 26.8 % higher than those of 60 kg N/ha. Significantly higher values of yield attributes were recorded under 12 kg N/ha as compared to 60 kg N/ha. Higher yield under high N level was due to adequate N supply which contributed to increased dry-matter production and well developed sink and source capacity of the plant resulted in increase in all yield attributing characters. Similar results were obtained by Rao *et al.* (1993).

Planting methods influenced the nitrogen uptake significantly at all the stages. On an average, significantly higher nitrogen uptake (27.0, 34.46, 58.06 and 75.7 kg/ha) were recorded under transplanting method at 60, 80, 100 and 120 days after sowing which were 5.5 and 11.2 at 60 days after sowing, 5.1 and 11.5 at 80 days after sowing, 6.5 and 14.3 at 100 days after sowing and 9.1 and 17.7% at 120 days after sowing than those of broadcasting and direct seeding methods, respectively. It might be due to higher grain and straw yield which reflected the higher nitrogen uptake as various methods did not affect the nitrogen content of grain and straw significantly. Urea super granule treated plot recorded significantly maximum nitrogen uptake of 84.51 kg N/ha at 120 days after sowing which was 15.5 % higher than prilled urea. Similar trend were noted at 60, 80 and 100 days stage during both the years of investigation. It was only due to increased dry-matter accumulation as well as N-concentration of both grain and straw.

There was significant increase in nitrogen uptake at all the growth stages with increasing level of nitrogen. On an average, 120 kg N/ha increased the nitrogen uptake by 44.2, 43.9, 42.3 and 39.0 % over 60 kg N/ha at 60, 80, 100 and

120 days after sowing respectively. Higher uptake under higher dose of nitrogen was due to better root establishment, translocation of absorbed nutrients from soil, higher plant growth and yield. Adequate N in the root zone increased the movement of N in soil solution and ultimately their absorption by the grains in plants.

The nitrogen use efficiency and recovery were higher under transplanting method. This was due to the fact that puddling reduced the weed population as well as the rate of infiltration and N become more available to the plant resulting higher yield and efficiency. Direct seeding showed minimum recovery of N, probably due to higher losses of applied N through leaching process through weeds uptake.

The nitrogen-use efficiency with urea super granule and prilled urea ranged between 25 to 34% during both the years. The maximum nitrogen-use efficiency was recorded with urea super granule during both the years. Higher nitrogen-use efficiency and apparent recovery with urea super granule may be due to the regulated release of nitrogen. Placement below oxidised zone of soil minimized the loss of N. Reddy and Reddy (1986) had reported that placement of nitrogen as urea super granule resulted in a higher uptake of nitrogen by about 15-17 % over split application of prilled urea. Craswell *et al.* (1981) observed that split applied prilled urea was inferior to urea super granule and sulphur coated urea with respect to apparent N recovery, which ranged from 30% for delayed split applied prilled urea to 80% urea super granule. The nitrogen use efficiency and apparent recovery with prilled urea and urea super granule reduced with increasing level of nitrogen applied. Increasing amount of nitrogen applied had more chances of nitrogen loss from soil over its lower levels

Table 2 Nitrogen uptake, apparent recovery and nitrogen use efficiency as influenced by planting method source and level of nitrogen

Treatments	Nitrogen uptake (kg/ha) (mean)				Apparent recovery (%)		Nitrogen use efficiency (kg grain/kg N)	
	Days after sowing				1996-97	1997-98	1996-97	1997-98
	60	80	100	120				
<i>Planting method</i>								
Transplanting	27.90	34.46	58.07	75.10	55.34	55.97	34.44	29.68
Broadcasting	25.57	32.80	54.46	69.43	52.45	52.88	29.91	27.74
Direct seeding	24.29	30.93	50.79	64.32	46.80	47.82	25.58	25.65
LSD (<i>P</i> =0.05)	1.03	1.48	2.92	2.46				
<i>Nitrogen source</i>								
Prilled urea	26.58	33.96	56.59	73.18	45.27	45.67	26.66	25.35
Urea super granule	31.68	40.45	67.15	84.51	57.78	58.78	33.29	30.04
LSD (<i>P</i> =0.05)	0.89	1.03	2.00	2.51				
<i>Nitrogen level</i>								
*0	11.57	14.80	24.72	33.68				
60	23.86	30.49	51.08	65.99	55.05	54.41	32.99	31.60
120	34.40	43.93	72.66	91.70	48.00	50.03	26.96	23.79
LSD (<i>P</i> =0.05)	0.89	1.03	2.00	2.51				

* Control versus treatment - significant

because of more release of nitrogen at a time. Reduction in efficiency and apparent recovery with increasing levels of applied nitrogen is also reported by Reddy and Reddy (1986).

Transplanting method proved to be the best for maximum grain yield (4.53 tonnes), nitrogen use efficiency (32.06) and apparent recovery (55.66%). Deep placement of urea super granule effectively increased N-use efficiency (21.8%) as compared to conventionally applied urea.

REFERENCES

- Craswell E T, De Datta S K, Obcemaz W N and Hartuntyo M. 1981. Time and mode of nitrogen fertilizer application to tropical wet land rice. *Fertilizer Research* 2 : 247-59.
- Rao K S, Moorthy B T S, Lodh S B and Sahoo K. 1993. Effect of graded levels of nitrogen on yield and quality of different varieties of scented rice in coastal Orissa. *Indian Journal of Agricultural Sciences* 63 (8) : 467-72.
- Reddy, Ramsubha G and Reddy Anand K. 1986. Uptake and apparent recovery of nitrogen by rice as influenced by nitrogen levels and forms of urea. *Journal of Research, APAU XIV/2* : 106-11.
- Saha G P and Mitra B N. 1988. Relative efficiency of urea, SCU, USG and LCU in rice. *Indian Journal of Agronomy* 31 (1) : 109-11.
- Sarvanan A, Velu V and Ramanathan K M. 1988. Effect of sources and methods of nitrogen application on volatilisation loss of ammonia and yield of rice under submerged soils of Cauvery delta, India. *Oryza* 25 : 143-8.
- Singh K M, Pal S K, Verma U N, Thakur R and Singh M K. 1997. Effect of time and methods of planting on performance of rice cultivars under medium land of Bihar plateau. *Indian Journal of Agronomy* 42 (3) : 443-5.

Yield and response of rice (*Oryza sativa*) as influenced by methods and sources of micronutrient application

M DATTA¹ and K R DHIMAN²

ICAR Research Complex for NEH Region, Lembucherra, Tripura (West) 799 210

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Among the micronutrients, zinc deficiency is the most widespread nutritional disorder in Indian soils for cultivation of rice. About 43 % samples in India have available Zn content in the deficient range (Takkar 1996). But in soils having marginally available zinc, higher amount of zinc is required in iron toxic soils particularly under submergence to mitigate its adverse effect (Agarwala *et al.* 1970). Soils of north-east India in lowland conditions are generally rich in iron and manganese while soils of upland conditions show Al- toxicity owing to the presence of soil acidity (Datta and Gupta 1984, Datta *et al.* 1991). The micronutrient stress that causes low crop productivity in soils of north-east India is mainly due to Fe/Al antagonism. An attempt was made to study the responses of rice to micronutrient application in both upland and lowland situations.

Field experiments were conducted during 1994-95 and 1995-96 in ICAR Research Complex Farm, Lembucherra, Tripura to find out the effect of micronutrients on rice productivity both in upland (Typic Paleochults) and lowland (Typic Haplaquents) situations. Experiment I with the soil application of micronutrients, viz T₀ (control), T₁ (10 kg ZnSO₄ / ha), T₂ (15 kg ZnSO₄ / ha), T₃ (30 kg ZnSO₄ / ha), T₄ (5 kg CuSO₄ / ha), T₅ (10 kg CuSO₄ / ha), T₆ (15 kg CuSO₄ / ha), T₇ (2 kg boric acid / ha), T₈ (5 kg boric acid / ha), T₉ (8 kg boric acid / ha), T₁₀ (0.5 kg ammonium molybdate / ha), T₁₁ (1.5 kg ammonium molybdate / ha), T₁₂ (2.5 kg ammonium molybdate / ha) was conducted in upland rice ('AR 11'). Experiment II with the similar micronutrient doses was conducted in lowland rice ('CR-75-93-Mut-11-4'). Experiment III was also conducted in lowland rice and the foliar micronutrient treatments in 1% solution were T₀ (control), T₁ (1 kg ZnSO₄ / ha), T₂ (2 kg ZnSO₄ / ha), T₃ (3 kg ZnSO₄ / ha), T₄ (1 kg CuSO₄ / ha), T₅ (2 kg CuSO₄ / ha), T₆ (3 kg CuSO₄ / ha), applied as single spray at tillering stage, T₇ (0.5+0.5 kg ZnSO₄ / ha), T₈ (1.0+1.0 kg ZnSO₄ / ha), T₉ (1.5+1.5 kg ZnSO₄ / ha), T₁₀ (0.5+0.5 kg CuSO₄ / ha), T₁₁ (1.0+1.0 kg CuSO₄ / ha) and T₁₂ (1.5+1.5 kg CuSO₄

/ ha) applied as two split sprays at tillering and flowering stages.

A pot experiment IV was conducted with rice ('TRC 246-C-10') to investigate the efficiency of zinc sources and the treatments were T₀ (control), T₁ (ZnSO₄), T₂ (Zn-Ca-polyphosphate), T₃ (ZnOAc), T₄ (ZnO), T₅ (ZnCl₂), T₆ [Zn (NO₃)₂] and T₇ (ZnCO₃) applied as 20 mg Zn/kg. Similar field trial (Experiment V) with micronutrient sources was conducted in lowland rice ('TRC-246C-10') and the treatments were T₀ (control), T₁ (NPK, 80:40:40), T₂ (10 kg ZnSO₄ / ha), T₃ (15 kg ZnSO₄ / ha), T₄ (15 kg ZnSO₄ / ha + NPK), T₅ (Multiplex @ 15 kg ZnSO₄ / ha), T₆ (Multiplex + NPK), T₇ (15 kg chelated Zn / ha), T₈ (15 kg chelated Zn / ha + NPK). Direct (Experiment VI) and residual (Experiment VII) effect of applied micronutrients were also made in rice-rice cropping systems in lowlands. The treatments were T₀ (control), T₁ (10 kg ZnSO₄ / ha), T₂ (15 kg ZnSO₄ / ha), T₃ (2 kg boric acid / ha), T₄ (5 kg boric acid / ha), T₅ (0.5 kg ammonium molybdate / ha), T₆ (1.5 kg ammonium molybdate / ha), T₇ (2.5 kg ammonium molybdate / ha), T₈ (15 kg ZnSO₄ / ha + 5 kg boric acid / ha), T₉ (15 kg ZnSO₄ / ha + 1.5 kg ammonium molybdate / ha), T₁₀ (5 kg boric acid / ha + 1.5 kg ammonium molybdate / ha) and T₁₁ (15 kg ZnSO₄ / ha + 1.5 kg ammonium molybdate / ha). Multiplex of Karnataka Agrochemicals make, contains 7% Zn, 0.6% Fe, 2% Mn, 0.1% Cu, 0.02% Mo and 0.6% B on dry weight basis. Chelated zinc is in the form of Zn - EDTA and contains 12% Zn. In all the field trials, NPK doses @ 60:30:30 and 80:40:40 were applied for upland and lowland rice respectively. Grain and dry matter yield were recorded at harvest.

Grain and dry matter yield recorded after harvest are presented in Table 1. In experiment I, the application of 15 kg ZnSO₄ / ha (T₂), 5 kg boric acid / ha (T₈) and 1.5 kg ammonium molybdate / ha (T₁₁) gave 15.7, 30.8 and 37.2 % significant increase in grain yield over control as against 39.3, 22.8 and 19.8 % increase recorded in experiment II. This indicated high response of upland rice to B and Mo probably due to their low availability in upland soils (0.4 mg B/kg and 0.13 mg Mo/kg) compared to lowlands (0.7 mg B/kg and 0.16 mg Mo/kg). Moreover the available B and Mo

¹Senior Scientist and ²Joint Director, ICAR Research Complex for NEH Region, Lembucherra, Tripura (West) 799 210

Table 1 Effect of soil and foliar application of micronutrients on the yield of rice

Treatment	Upland rice (Experiment I)			Lowland rice					
	Grain yield (kg/ha)	Dry matter (kg/ha)	Harvest index(%)	Grain yield (kg/ha)		Dry matter		Harvest index(%)	
				Expt II	Expt III	Expt II	Expt III	Expt II	Expt III
T ₀	1 171	1 392	84.1	2710	3 451	4 667	4 020	58.1	85.8
T ₁	1 292	1 420	90.9		3 630		4 051		89.6
T ₂	1 355	1 672	81.0	3227	3 650	6 500	4 672	49.6	78.1
T ₃	1 287	1 420	90.6	3170	3 732	6 320	4 670	50.2	79.9
T ₄	1 420	1 678	84.6	2725	3 221	4 500	4 503	60.6	71.5
T ₅	1 208	1 678	71.9	2860	2 872	4 330	3 330	66.1	86.2
T ₆	1 105	1 525	72.5	2690	3 433	6 662	4 020	40.4	85.4
T ₇	1 376	1 670	82.4	2783	3 870	4 330	5 150	64.3	75.1
T ₈	1 532	1 721	89.0	3327	3 621	5 332	4 520	62.4	80.0
T ₉	1 432	1 640	86.6	2963	3 690	5 661	5 075	52.3	72.7
T ₁₀	1 430	1 663	85.9	2623	3 183	5 660	4 060	46.3	78.4
T ₁₁	1 607	1 709	94.0	3247	3 030	6 000	4 020	54.1	75.4
T ₁₂	1 306	1 822	71.7	2950	3 275	5 670	4 021	52.0	81.4
CD (P=0.05)	78	109		356	225	1812	NS		

contents in uplands soils were below their respective critical levels (0.5 and 0.15 mg/kg). Panda (1987) reported that all acid soils of eastern India were deficient in B and Mo and several crops showed responses to their application either through soil or as a spray material.

Data (Table 1) further indicated enhanced response of lowland rice (Experiment II) to Zn application inspite of high zinc availability (3.1mg/kg). High DTPA extractable Fe (23.8 mg/kg) and Mn (33.6 mg/kg) might have produced an antagonism (Datta and Ram 1993) to zinc availability in plants. Sen *et al.* (1997) reported that available Fe was negatively correlated with available Zn ($r=0.59^*$) thus corroborating the phenomenon of antagonism. Furthermore, similar findings related to Zn $\times$ Mn and Zn $\times$ Fe antagonism were reported (Singh *et al.* 1990) probably due to adsorption or fixation with Al and ferroxides besides leaching in heavy rain in soils of high altitude region in Meghalaya. Similar response of rice to micronutrients was reported by workers (Singh 1990) in acid soils rich in sesquioxides. Upland and lowland rice did not show any response to the application of CuSO₄. Harvest index varied from 71.7 – 90.9 and 40.4 – 66.1% in upland and lowland rice respectively thus indicating the enhanced biomass production in transplanted rice.

The nature of response of applied micronutrients to rice can be expressed by the following quadratic equations.

Upland rice

$$Y = 1 167.52 + 19.04 X_1 - 0.50 X_{12}$$

$$Y = 1 165.95 + 136.72 X_2 - 13.06 X_{22}$$

$$Y = 1 268.46 + 599.93 X_3 - 258.18 X_{32}$$

Lowland rice

$$Y = 2 710.02 + 53.61 X_1 - 1.28 X_{12}$$

$$Y = 2 625.54 + 214.04 X_2 - 20.75 X_{22}$$

$$Y = 2 591.30 + 598.57 X_3 - 174.76 X_{32}$$

In the equations, Y is yield and X₁, X₂, X₃ correspond to Zn, B and Mo respectively. From the quadratic regression model, it is found that grain yield without micronutrients varied from 1 167 to 1 268 and 2 591 to 2 710 kg/ha in upland and lowland soils respectively.

The quadratic term was of highest magnitude in Mo followed by B and Zn implying that the decline in yield would be larger after the application of higher Mo doses as compared to two other micronutrients. The response equations were allowed to differentiate with respect to micronutrients. The differentials thus obtained are as follows.

Upland rice

$$dY/dZn = 19.04 - 1.0 X_1$$

$$dY/dB = 136.72 - 26.12 X_2$$

$$dY/dMo = 599.83 - 516.36 X_3$$

Lowland rice

$$dY/dZn = 53.61 - 2.66 X_1$$

$$dY/dB = 214.04 - 41.50 X_2$$

$$dY/dMo = 598.57 - 349.52 X_3$$

These differentials were of use to find out the micronutrient doses for maximisation in response and to subsequently predict the maximum yield. After equating the differentials to zero, the gradient of the response curve would not exist as no further yield increase was possible. With a view to get maximisation in response from the differentials, the doses of zinc sulphate, boric acid and ammonium molybdate in uplands were 19.04, 5.23 and 1.16 kg/ha with the corresponding yield prediction of 1 349, 1 524 and 1 617 kg/ha respectively. In lowlands, the doses of zinc sulphate, boric

Table 2 Effect of micronutrient sources and their combinations on the yield of rice

Treatment	Experiment IV			Experiment V			Experiment VI			Experiment VII		
	Grain yield (kg/ha)	Dry matter (kg/ha)	Harvest index (%)	Grain yield (kg/ha)	Dry matter (kg/ha)	Harvest index (%)	Grain yield (kg/ha)	Dry matter (kg/ha)	Harvest index (%)	Grain yield (kg/ha)	Dry matter (kg/ha)	Harvest index (%)
T ₀	9.0	18.0	50	3 344	7 330	46	2 733	3 833	71	2 850	4 200	68
T ₁	12.3	22.3	55	4 206	8 130	52	2 333	3 333	70	2 833	4 900	58
T ₂	12.0	25.0	48	3 903	6 930	56	3 161	3 500	90	2 883	5 450	53
T ₃	12.3	29.0	42	3 969	7 930	50	3 161	3 500	90	3 070	5450	56
T ₄	17.6	29.3	60	4 340	7 200	60	3 257	3 500	93	3 200	4 330	74
T ₅	13.0	24.0	54	3 940	6 130	64	3 002	4 167	72	2 570	3 200	80
T ₆	12.3	27.0	46	4 510	7 920	57	3 400	3 933	86	3 440	4 550	76
T ₇	10.7	19.0	56	3 390	5 000	68	2 933	3 667	80	2 030	3 220	63
T ₈				3 790	7 730	49	2 733	3 500	78	2 650	3 840	69
T ₉							3 533	4 000	88	3 570	4 200	85
T ₁₀							2 950	4 833	61	2 883	4 580	63
T ₁₁							3 400	3 567	95	2 650	4 200	63
CD (P=0.05)	2.54	4.57		430	495		279	350		646	NS	

acid and ammonium molybdate were 20.94, 5.16 and 1.71 kg/ha thereby predicting the production of 3 271, 3 181 and 3 104 kg/ha respectively.

In experiments III (Table 1), the foliar spray (0.5%) of ZnSO₄ (0.5 + 0.5 kg / ha) in T₇ gave the maximum rise (12.1%) in grain yield over control. The foliar spray of ZnSO₄ was not as effective as its basal application. Foliar application of CuSO₄ did not show any significant response.

All other Zn sources except ZnCO₃ (Table 2) could produce significantly higher grain yield in experiment IV with 33.3 – 95.6% increase over control. The results of harvest index could reveal the following trend of responses due to application of different sources of Zn :

ZnO > ZnSO₄ > ZnCl₂ > Zn- Ca- polyphosphate > Zn(NO₃)₂ > ZnOAc.

Out of the various commercially viable Zn fertilizer, multiplex in combination with NPK(T₇) in experiment V gave the maximum increase (34.8%) in grain yield over control. Harvest index was also increased from 46 to 57 % in T₇. The results (Table 2) indicated that 15 kg ZnSO₄ / ha + 1.5 kg ammonium molybdate / ha in T₉ gave the maximum increase (29.3%) in grain yield in experiment VI. This combination of Zn and Mo was also observed to gave 25.3% increase in grain yield in residual trial (Experiment VII). Harvest index in T₉ was also increased from 71.3 – 88.3 and 67.9 – 85.0 % in experiment VI and VII respectively. All other micronutrient levels failed to give any significant increase in yield in residual experiment. Field experiments conducted in both upland and lowland indicated significant response of rice to the application of Zn, B and Mo in acid soils of Tripura.

REFERENCES

- Agarwala S C, Mehrotra N K, Sharma C P, Ahmed S and Sharma V K. 1970. Wide spread occurrence of zinc deficiency in eastern region of Uttar Pradesh. *Journal of the Indian Society of Soil Science* 18 (4) : 415-28.
- Datta M and Gupta R K. 1984. Studies on micronutrient status in acid soil of Nagaland. *Indian Agriculturist* 28 (3) : 221-3.
- Datta M, Laskar S and Prasad R N. 1999. Appraisal of charge characteristics in some soil series of Tripura. *Journal of the Indian Society of Soil Science* 39 : 767-9.
- Datta M and Ram M. 1993. Status of micronutrients in some soil series of Tripura. *Journal of the Indian Society of Soil Science* 41 : 776-77.
- Gangwar M S and Mann J S. 1972. Zinc nutrition of rice in relation to iron and manganese uptake under different water regimes. *Indian Journal of Agricultural sciences* 42 (11) : 1 032-5.
- Panda N. 1987. Acid soils of eastern India their chemistry and management. *Journal of the Indian Society of Soil Science* 35 (4): 568-81.
- Prasad R N and Singh B P. 1987. Agronomic and environmental constraints on fertilizer consumption in the North-Eastern India. North Eastern Council, pp 27-37.
- Sen T K, Dubey P N, Maji A K and Chamuah G S. 1997. Status of micronutrients in some dominant soils of Manipur. *Journal of the Indian Society of Soil Science* 45 (2) : 388-90.
- Singh B P, Singh A and Singh B N. 1990. Response of rice (*Oryza sativa*) to zinc and boron application in acid Alfisols under mid altitude conditions of Meghalaya. *Indian Journal of Agricultural Sciences* 60 (1) : 70-1.
- Takkar P N. 1996. Micronutrient research and sustainable agricultural productivity in India. *Journal of the Indian Society of Soil Science* 44 (4) : 562-81.

Effect of herbicides on nodulation, yield and weed control in soybean (*Glycine max*)

S D BILLORE¹, O P JOSHI² and A RAMESH³

National Research Centre for Soybean, Indore, Madhya Pradesh 452 017

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Key words: herbicides, nodule, soybean, weed

Weeds compete with crop plants for natural resources and have wide adaptability. Of the total loss of agricultural produce, weed account for 45 %, insects 30 %, diseases 20 % and others 5 % (Rao 1983). Herbicides is the largest class of pesticides frequently used to reduce serious yield losses caused by weeds. However, their use may restrict symbiosis between leguminous plants and nitrogen fixing bacteria. Detrimental effect of pesticides on legume-Rhizobium symbiosis can probably be attributed to complex factors rather than one that can easily be identified (Schnella and Hensley 1990). Hence, a study was initiated to ascertain the effect of different herbicides on nodulation and control efficiency and soybean (*Glycine max* (L.) Merr.).

A field experiment was conducted at research farm, Indore during rainy season 1997 and 1998 on Vertisols. Fourteen treatments (Table 1) were laid out in randomized block design with three replications, 'JS 335' soybean was sown on 26 June and 2 July in 1997 and 1998, respectively. Pre-treated seed (75 kg/ha) with thirum + carbendazim (1:1) (@ 3 g/kg seed) followed by inoculation with *Bradyrhizobium japonicum* culture (@ 5 g/kg seed) was utilized. A uniform dose of 20:26.2:16 kg/ha was applied as basal.

Trifluralin was applied as pre-plant incorporation. Post-emergence herbicides were sprayed 15 to 20 days after sowing. These herbicides were sprayed using 800-litres of water/ha. Two-hand weeding and 2-intercultivation (farmer's practice) were carried out on 3rd and 6th weeks after sowing. Randomly selected 3 plants were carefully sampled at flowering and utilized for nodule enumeration. The oven dried weight of nodules and plant was recorded. Pooled data for the two years was statistically analyzed and presented.

The prominent weed species encountered during the experimentation were as: *Echinochloa crus-galli* (L.) P. Beauv. (sanwa grass), *Dinebra arabica* (Karna grass), *Digitaria sanguinalis* (crab grass), *Cyperus rotundus* L. (nut sedge), *Cynodon dactylon* (doob grass), *Euphorbia geniculata* (bari doodhi), *Digera arvensis* (lahsua), *Eclipta alba* (bhangra),

Corchorus olitorius (jangle jute) and *Acalypha indica* (kuppi).

Consequent to selected application of herbicide, a significant effect on plant dry matter, nodules/plant and their dry biomass were recorded (Table 1). All the weed management treatments resulted in numerically higher plant dry matter over weedy check. Maximum dry matter accumulation was associated with application of pendimethalin @ 1 kg/ha followed by propaquizafop @ 75 g/ha and imazethapyr @ 75 g/ha. However, these treatments were on a par with propaquizafop (50 g/ha) and alachlor (2 kg/ha). The increase in soybean dry matter production can be associated with (i) decrease in concentration of chlorophyll and carotenoids, (ii) carbon partitioning between reducing and non-reducing sugar, and (iii) increase in amino acids and endogenous hormones. Therefore growth promoting and inhibitory effects of herbicides on dry matter production might be ascribed to changes in several metabolic and physiological perturbations (Ahmed and Rashad 1996).

The maximum and minimum nodules were associated with application of fenoxoprop-p-ethyl @ 70 g/ha and 2-hand weeding, respectively. The lowest nodule count in the case of 2 hand weedings may be attributed to soil disturbances, which might have affected root growth and consequent poor nodulation. All weed management treatments showed nodule count on a par with except 2-hand weeding which was significant lower and on par to weedy check.

The nodule dry weight was maximum in 2-intercultivation, whereas it was minimum with weedy check. The minimum value associated with weedy check was significantly lower than 2- intercultivation, lectofen (90 g/ha), imazethapyr (75 g/ha). Propaquizafop (75 g/ha), fenoxoprop-p-ethyl (70 g/ha) and trifluralin (1 kg/ha). Invariably higher nodule dry weight in all the treatments than weedy check indicated that by and large the nodulation was promoted by these weed management practices.

The herbicides, among themselves, showed differential (Schnella and Hensley 1990) influence on nodulation as indicated by these two parameters. On the contrary, adverse effect of application of trifluralin (Udoh and Nelson 1986) and alachlor (Kao and Wang 1981) on nodulation has been documented. Sandhu (1984) found no adverse effect by

*Short note

¹Scientist (Agronomy), ²Principal Scientist, ³Scientist (Soil Science)

Table 1 Effect of different herbicides on nodulation, weeds and yield of soybean (pooled over 1997 and 1998)

Treatment	Dose (kg/ha)	Applic- -ation mode	Plant dry weight (g)	Nodule		Weeds				Seed yield (kg/ha)	Weed efficiency (%)		control
				Num- ber	Dry weight (g)	Count		Dry biomas			30 DAS	60 DAS	
						(No./m ²)		(g/m ²)					
						30	60	30	60				
						DAS	DAS	DAS	DAS				
Alachlor	2.000	PE	18.05	68	191	39	13	19.29	14.03	1 296	35.66	50.73	
Trifluralin	1.000	PPI	14.58	79	240	11	12	10.92	13.16	1 424	63.57	53.79	
Pendimethalin	1.000	PE	23.51	81	181	20	9	11.71	20.06	1 361	60.94	29.56	
Fenaxoprop-p-ethyl	0.050	POE	15.50	61	205	19	11	23.17	22.91	1 754	22.71	19.55	
Fenaxoprop-p-ethyl	0.070	POE	14.53	87	254	22	13	21.49	23.99	1 413	28.32	15.76	
Propaquizafop	0.050	POE	18.96	57	182	18	12	17.89	14.88	1 397	40.33	47.75	
Propaquizafop	0.075	POE	21.42	67	235	19	17	24.58	18.64	1 433	8.00	34.55	
Anilophos	1.500	POE	16.27	70	189	20	15	18.52	26.56	1 130	38.22	6.74	
Imazethapyr	0.100	POE	20.40	70	259	30	39	9.64	9.46	1 754	67.84	66.78	
Imazethapyr	0.075	POE	17.40	56	169	40	28	17.50	11.50	1 565	41.62	59.62	
Lectofen	0.090	POE	12.18	78	247	57	37	32.81	17.34	1 217	-9.49	39.11	
2-hand weedings			11.76	35	213	37	28	4.88	17.93	1 855	83.72	37.04	
2-intercultivations			14.60	77	277	49	23	16.36	28.87	1 399	45.33	-1.37	
Weedy check			9.20	75	134	71	25	29.98	28.48	944			
CD (p=0.05)			5.99	22	95	26	16	15.66	23.64	212			

PPI, Pre-plant incorporation; PE, pre-emergence; POE, post-emergence

application of metabenzthiazuran and terbutryn. Ahmed and Rashad (1996) reported differential behaviour based on the changes in the endogenous plant hormonal contents in nodule specific to particular herbicide to determine changes in nodule dry weight.

The data on weed count indicated that almost all herbicides controlled weeds effectively at 30 days after sowing sans lectofen and 2-intercultivations. At 60 days after sowing, lectofen and imazethapyr did not influence the number of weeds but showed reduction in dry weight of weeds. Increased weed biomass was recorded with lectofen @ 90 g/ha and 2-intercultivations at 30 and 60 days after sowing. This could be accounted for control of dicot weeds only by lectofen (Billore *et al.* 1997) and leftover weeds within soybean rows.

Application of imazethapyr @ 100 g/ha resulted in maximum yield and was on par with imazethapyr @ 75g/ha, fenaxoprop-p-ethyl @ 50 g/ha and 2-hand weedings. This corroborates with the findings of Porwal *et al.* (1990) who reported that the chemical weed control and manual weeding were equally effective in reducing the weed intensity in soybean. The increased yield with application of imazethapyr can be ascribed to its weed control efficiency, lesser impact on microbial and enzymatic activities resulting decreased adverse effect on nutrient cycling (Auspurg *et al.* 1989) and stimulatory effect on metabolic and physiological processes (Berger and Heitefuss 1991).

REFERENCES

- Ahmed A H H and Rashad M H. 1996. Comparative studies on the effect of fusillade in cora and soybean plants. *Bulletin of Faculty of Agriculture, University of Cairo*, pp 570-610.
- Aspurg B, Pestemer W and Heitefuss R. 1989. Studies on the effect of a pesticides spray sequence on the behaviour of terbutryn residues and on soil microbial activity. II. Influence on microbial activity. *Weed Research* 29 : 71-91.
- Berger A and Heitefuss R. 1991. Use of isoproturon alone and in combination with other compounds post-emergence in winter and spring on winter wheat and winter barley. II. Side effects on dehydrogenase activity, nitrogen formation and straw decomposition in soil. *Weed Research* 31 : 1-18.
- Billore S D, Joshi O P and Ramesh A. 1997. Comparative performance of weedicides in soybean. *Pestology* 21 (11):43-5.
- Kao T C and Wang C C. 1981. Study on effect of herbicides on growth of rhizobia and development of root nodules. *Journal of Agricultural Association, China, Microbial Abstract* 17 (2) : 1 215.
- Porwal M K, Nanawati G C and Bhatnagar G S. 1990. Efficacy of herbicidal control of weeds in soybean. *Indian Journal of Agricultural Sciences* 60 (2):132-6.
- Rao V S. 1983. *Principals of Weed Science*. Oxford and IBH Publishing Company, New Delhi.
- Sandhu P S. 1984. 'Effects of sowing dates, phosphorus levels and herbicides on response of rhizobium in lentil'. Ph D thesis Punjab Agricultural University, Ludhiana.
- Schenella M A and Hensely D L. 1990. Effects of pesticides upon nitrogen fixation and nodulation by dry bean. *Pesticide Science* 28 : 83-8.
- Udoh DJ and Nelson L E. 1986. Trifluralin induces chlorosis in soybean grown on clayey high pH soil. *Plant and Soil* 96:175-84.

Response of rainfed mustard (*Brassica juncea*) to sulphur and phosphorus on Inceptisol in mid hill-intermediate zone of Jammu and Kashmir

M P SHARMA¹ and V K JALALI²

Regional Agricultural Research Station, Sher-e-Kashmir University of Agricultural Sciences and Technology,
R S Pura, Jammu 181102

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Sulphur and phosphorus play important role in improving the quality and quantity of oilseeds. Sulphur is an integral part of S containing amino acids and is required for the synthesis of proteins and oils. Phosphorus stimulates seed setting, hasten maturity and provides extensive and vigorous root system. The available information on S and P interaction on yield and their uptake is conflicting, as both synergistic and antagonistic effect have been reported (Tandon 1989). Since information on this aspect under mid-hill intermediate zone of Jammu and Kashmir is lacking. Therefore, the present investigation was undertaken to study the response of rainfed mustard to sulphur and phosphorus.

A field experiment was conducted during winter season of 1994-95 and 1995-96 under rainfed condition at Rajouri. The texture of experimental plots is clay with group of Inceptisol. The average rainfall received during the year was 1200 mm. The surface soil of experimental field (0-15 cm) had pH 7.1, EC 0.25 ds/m, organic carbon 4.5 g/kg, available N, P, K and S 305.0, 12.8, 182.0 and 8.5 kg/ha respectively. The 16 treatments consisting of four levels each S (0, 20, 40 and 60) through CaSO_4 and P_2O_5 (0, 20, 40, and 60) through triple super phosphate with three replications. The experiment was laid out in factorial randomised block design. Basal dose of 40 kg N and 20 kg K_2O was applied through urea and muriate of potash respectively var 'RLM 198' mustard [*Brassica juncea* (L.) Czernj. and Cosson] was raised as per package and practices. Seed and straw yield was recorded as per the treatments plant samples were digested in HNO_3 : HClO_4 in 4:1 mixture and P and S in plants were determined by vanadomolybdate phosphoric acid colour and turbidimetrically methods respectively (Jackson 1965). The oil content of seed samples was determined with petroleum ether using soxhlet extraction assembly and oil yield was worked out by multiplying oil content with respective seed yield (AOAC Washington DC 1965).

Seed and straw yield: The seed and straw yield increased significantly with increase in levels of S (Table 1) The increase

in yield may be due to higher rate in protein synthesis and enhanced photosynthate activity of plant with increased chlorophyll synthesis due to fertilization with sulphur (Biswas *et al.* 1995). Similarly P also enhanced the grain and straw yield. However, the effect was limited to P application up to 40 kg/ha. The response of higher yield to P may be due to optimum plant development and better transformation of photosynthate to the site of pod formation. Significant interaction effect of S and P was observed in both seed and straw yield of mustard. With each increase in S and P levels, seed and straw yield continued to increase till at S_{60} and P_{40} . However significantly higher yield of seed (1.47 tonnes/ha) and straw (4.47 tonnes/ha) was observed up to S_{60} and P_{40} kg/ha. The additive effect of combined application of S and P might be owing to the balanced nutrition and increased yield contributing characters. These findings are in line with those reported by Jaggi and Sharma (1997). The higher dose of combined application declined the seed and straw yield of mustard. This may be due to suppressed availability of each other. These results are in agreement with Aulakh *et al.* (1990).

Nutrient uptake: The total uptake of S increased significantly with increase in each dose of S upto 60 kg/ha (Table 2). The per cent increase in total S uptake was 42, 61 and 74 over control with the application of S at 20, 40 and 60 kg/ha, respectively. The increased uptake of S by mustard could be due to higher demand of crop for sulphur (Biswas *et al.* 1995). Sulphur uptake also increased from 18.09 to 27.12 kg/ha due to application of phosphorus at zero and 40 kg P/ha respectively. Sulphur application also influenced total P uptake up to 40 kg/ha beyond which P uptake was decreased. The significant decrease in P uptake at higher rate of S application probably because of P has been met at lower S application rate Jaggi and Sharma (1997). Moreover, P uptake by mustard is less as compared with S uptake. Synergistic effect of combined application of S and P at lower and medium level on their uptake was observed. The maximum S uptake (31.86 kg/ha) and P (9.82 kg/ha) uptake was recorded with S_{60} and P_{40} and P_{60} and S_{40} , respectively. The higher doses of combined application decreased their uptake, explaining antagonistic effect of each other.

* Short note

¹Senior Scientist (Soils), T&V ²Senior Scientist (Soils)

Table 1 Effect of sulphur and phosphorus on yields (tonnes/ha) of mustard

P levels (kg/ha)	S levels (kg/ ha)					S levels (kg/ ha)				
	Seed yield (tonnes/ha)					Staw yield (tonnes/ha)				
	0	20	40	60	Mean	0	20	40	60	Mean
0	0.522	0.885	1.175	1.175	0.924	1.618	2.872	3.510	3.718	2.929
20	0.840	1.118	1.248	1.338	1.136	2.912	3.425	3.715	3.980	2.508
40	1.010	1.245	1.386	1.478	1.280	3.455	3.758	4.265	4.470	3.987
60	1.102	1.260	1.415	1.412	1.297	3.412	3.782	4.228	4.256	3.919
Mean	0.868	1.127	1.291	1.350		2.849	3.459	3.929	4.105	
CD ($P=0.05$)	S=0.07	P=0.07	S×P=0.14		S=0.118	P=0.118	S×P=0.236			

Table 2 Effect of sulphur and phosphorus on their total S and P uptake (kg/ha); oil content (%) and oil yield (tonnes/ha) of mustard

P levels (kg/ha)	S levels (kg/ha)					S levels (kg/ha)				
	S-uptake					P-uptake				
	0	20	40	60	Mean	0	20	40	60	Mean
0	8.69	17.87	21.35	24.45	18.09	3.10	4.85	6.32	6.52	5.19
20	16.58	23.88	26.02	27.92	23.60	5.58	6.28	7.66	6.74	6.56
40	21.68	25.75	29.22	31.86	27.12	6.63	7.98	8.85	7.66	7.78
60	18.25	25.36	28.25	29.15	25.25	7.40	8.91	9.82	9.15	8.82
Mean	16.30	23.21	26.21	28.34		5.67	7.00	8.16	8.16	
CD (<i>P</i> =0.05)	S=1.27	P=1.27	S×P=2.54		S=0.48	P=0.48	S×P=0.96			
Oil content (%)						Oil yield (tonnes/ha)				
0	39.25	39.58	40.30	40.10	39.80	0.205	0.350	0.473	0.712	0.435
20	38.90	39.60	40.35	40.12	39.74	0.327	0.443	0.504	0.537	0.452
40	38.82	39.55	40.42	40.15	39.73	0.392	0.492	0.560	0.593	0.509
60	38.75	39.35	39.62	39.60	39.33	0.427	0.496	0.561	0.560	0.511
Mean	38.93	39.52	40.17	40.00		0.337	0.445	0.524	0.600	
CD (<i>P</i> =0.05)	S=0.58	P=0.58	S×P=NS			S=0.065	P=0.065	S×P=0.130		

Compatibility of sorghum (*Sorghum bicolor*) in teak (*Tectona grandis*)-based agroforestry system

S M MUTANAL¹, A S PRABHAKAR² and B S NADAGOUDAR³

University of Agricultural Sciences, Dharwad, Karnataka 580 005

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Agroforestry is considered to be sustainable land-use system mainly in the tropical world. The impact of degradation of forest are resulting in excessive soil erosion, degradation of watersheds, loss of biological diversity, climatic changes and reduction in economic contribution of forests to human life. Hence, to reduce pressure on existing forests, the agroforestry is necessary.

The compatibility of associated sorghum (*Sorghum bicolor* L.) with teak (*Tectona grandis* L.f.) depends upon site, soil and climatic factors and age, size and type of tree species. Yield reduction of winter season (*rabi*) sorghum was lowest with teak and subabul (*Leucaena leucocephala* (Lam) de Wit.) at Bijapur (Ital 1987). Teak plantations were intercropped with paddy and pulses (blackgram, horsegram, greengram) for first 2–5 years without any reduction in growth and yield of teak (Roder *et al.* 1995). Researchers noticed no adverse effect on the growth of teak when annuals (rice/pulses) were intercropped in teak plantation (Roder *et al.* 1995). A field experiment involving silvicultural crop (teak) and pasture crops (guinea grass- *Panicum maximum* L. and subabul) was initiated on red gravelly soils at Main Research Station of the University, Dharwad under rainfed conditions during 1984. Teak was planted at 10 m and 20 m alleys at 2 m intra row spacing. Along teak rows on either side, grass slips and 'K 8' subabul seedling were planted at 60 cm × 60 cm and 60 cm × 20 cm spacing respectively. Both grass and subabul were harvested for fodder purpose and served as live bund to prevent runoff of rain water and soil loss. 'CHS 5' sorghum crop was grown during 1996 and 1997 in between teak alleys. The fertilisers of 100:75:35 N:P:K kg/ha was applied annually. The rainfall of 683 and 708 mm was received during 1996 and 1997 respectively. The effect of teak on sorghum was studied up to 5 m distance on either sides (east and west direction) 10 and 20 m teak alley to fit for uniformity for statistical designs. The experiment was laidout in split-split plot in four replications.

Gross/net plot size was 8 m × 1 m. Soil-moisture was determined by gravimetric method at 60 cm depth.

Effect of teak alley

Grain yield was highest (2 898 kg/ha) with sole sorghum as compared to sorghum with teak (1 485 kg/ha), teak + grass (1 408 kg/ha) and teak + subabul (1 441 kg/ha). Annual yield of 4.34 and 1.55 tonnes/ha was obtained from guinea grass and subabul respectively. The average teak height and diameter at breast height were 9.03 m and 14.78 cm at the beginning of the study and 10.41 m and 16.43 cm at the end of the study respectively. The extent of reduction in the yield of sorghum was 48.7, 51.4, 50.2 % in sorghum grown with teak, sorghum with teak + grass, sorghum with teak + subabul respectively compared with sole sorghum. The straw yield production was higher in sole crop (3 976 kg/ha) as compared to the agroforestry systems, straw yield was decreased in association with teak (35 %), teak + grass (40 %) and teak + subabul (39%). Low yield of sorghum in agroforestry might be due to less soil-moisture and low light transmission ratio at 90 days after sowing of sorghum with teak (9.99 and 66 %), teak + grass (9.60 and 68.5 %), teak + subabul (9.3 and 69.8%) compared to sole sorghum (12.6 and 100 % respectively). The competition might have suppressed the growth of sorghum and reduced its yield. This can be clearly seen through reduction in plant height (20–26%), leaf area (35–38%), dry matter production (29–33%), effective plant population (43–45%). Although initial germination of sorghum was not affected under different agroforestry systems but plants either withered or gave smaller ear head. Low sorghum yield were obtained from adjoining rows of eucalyptus trees (Sharma *et al.* 1996).

Effect of distance from teak alley

Grain and straw yield of sorghum was reduced significantly nearer to the teak alley compared to 5 m from teak alley. The of reduction in grain yield was 39.8, 32.0, 20.6 and 7.7 % in 1, 2, 3 and 4 m from teak alley respectively compared to 5 m from teak alley. The reduction in straw yield was 42.4, 35.4, 23.7 and 10.9 % in 1, 2, 3 and 4 m teak alley respectively as

¹Scientist (Agroforestry), ²Director of Instruction (PGS), ³Senior Senior Scientist Agroforestry, Department of Forestry

Table 1 Grain and straw yield of sorghum as influenced by agroforestry system, direction and distance

DR/DS		Agroforestry system										
		Grain yield (kg/ha)					Straw yield (kg/ha)					
		S	S+T	S+T+G	S+T+Sb	Mean	S	S+T	S+T+G	S+T+Sb	Mean	
DR-W	DS	1	3 128	820	884	820	1 415	3 896	1 656	1 498	1 662	2 178
		2	2 916	1 256	1 020	1 156	1 587	3 905	2 052	1 896	1 943	2 449
		3	2 751	1 650	1 441	1 516	1 840	3 544	2 713	2 460	2 517	2 809
		4	2 858	1 991	1 900	1 859	2 152	4 131	3 285	3 056	2 937	3 353
		5	2 878	2 175	2 050	2 126	2 307	4 178	3 756	3 436	3 549	3 730
Mean			2 906	1 580	1 459	1 495	1 860	3 931	2 692	2 469	2 522	2 904
DR-E	DS	1	2 855	800	788	768	1 302	3 975	1 435	1 343	1 385	2 034
		2	2 781	1 139	982	1 027	1 480	3 942	1 863	1 728	1 586	2 279
		3	2 883	1 380	1 284	1 431	1 745	3 954	2 526	2 297	2 326	2 776
		4	2 731	1 659	1 785	1 743	1 979	4 127	2 915	2 831	2 806	3 169
		5	2 955	1 971	1 950	1 965	2 210	4 413	3 459	3 131	3 365	3 592
Mean			2 839	1 390	1 358	1 387	1 744	4 022	2 440	2 266	2 294	2 756
	DS	1	2 991	814	836	794	1 358	3 935	1 545	1 420	1 523	2 106
		2	2 971	1 197	1 000	1 091	1 534	3 923	1 958	1 812	1 765	2 364
		3	2 817	1 515	1 363	1 473	1 792	3 749	2 620	2 379	2 422	2 792
		4	2 794	1 825	1 842	1 801	2 083	4 129	3 100	2 944	2 872	3 261
		5	2 916	2 073	2 000	2 045	2 258	4 296	3 607	3 283	3 457	3 661
Mean for AFS			2 898	1 485	1 408	1 441	-	3 976	2 566	2 368	2 408	-
For comparison of			SEm±		CD (P=0.05)			SEm±		CD (P=0.05)		
AFS			58.6		174.1			77.6		230.5		
DR			12.5		34.7			25.1		69.8		
DS			18.4		51.1			39.8		110.3		
AFS-DR			25.0		69.4			50.3		139.6		
AFS-DS			36.9		102.3			76.6		220.7		
DR-DS			23.6		NS			56.3		NS		
AFS-DR -DS			47.3		NS			112.6		NS		

AFS, Agroforestry systems, viz S-Sole sorghum, S+T - sorghum +teak, S+T+G - Sorghum + teak + grass; S+T+Sb - sorghum +teak+subabul
 DR-W : Direction - western side of teak row, DR-E : direction - eastern side of teak row, DS - distance from teak row in metres (1-5)

compared to 5 m from teak alley. This may be due to lower soil moisture (8.98–10.6 %) availability at 1 m distance from teak alley compared to 5 m distance (11.7–13.2 %) throughout growing season. Lower light transmission ratio was observed in closer distance from teak rows as crown shading was higher around trees. This could directly affect plant height (12–48%), leaf area (11–21%), dry-matter production (9–35%) and effective plant population (9–26%). Similar observations were made by several workers from tree line (Chauhan *et al.* 1995 and Sharma *et al.* 1996).

Effect of direction from teak alley

Sorghum grain increased by 6.6 % on western side of teak alley than eastern side. This might be due to higher soil-moisture (10.8–12.1%) on western side as compared to eastern side (10.0–11.7 %). Teak alley forms an obstacle for western rainy season (*kharif*) rains and major portion of rainfalls on western side of teak alley, hence favours the growth of crops on western side as compared to eastern side. This can be

convinced through reduced plant height (10–12%), leaf area (5–8%), dry matter production (6–8%) and plant population (10–16%) on eastern side. Nadagoud (1990) observed higher reduction of maize (*Zea mays* L.) yield (34%) on eastern side of eucalyptus trees as compared to western side of tree line. Effect of interaction between agroforestry system vs direction was significant. Grain yield was increased by 10.3, 8.9, 9.9 % on western side of teak, teak + grass and teak + subabul as compared to their eastern sides. This might be due to higher soil-moisture content which favoured the growth of plant height, leaf area, dry-matter production, etc. The interaction effect between agroforestry system and distance was significant. Grain and straw yield of sorghum increased with increase in distance from teak alley in all agroforestry systems except in sole sorghum. Low yield near trees may be due to low soil-moisture, dry-matter production, grain and straw weight/plant. Interaction effect of direction vs distance, and agroforestry system vs direction vs distance were not significant. However, the trend was similar with that of main

Table 2 Soil moisture (%) as influenced by agroforestry system, direction and distance

DR/DS	Agroforestry system											
	Sowing				30 DAS				60 DAS			
	S	S+T	S+T+G	S+T+Sb	Mean	S	S+T	S+T+G	S+T+Sb	Mean	S	S+T
DR-W												
DS 1	13.92	11.08	9.53	9.06	10.90	13.73	9.81	8.56	8.83	10.23	13.90	8.12
9.22												8.28
2 14.25	11.88	9.12	10.09	11.33	13.68	10.44	9.88	9.94	10.98	13.65	9.15	9.72
3 13.78	12.91	10.33	11.24	12.07	13.48	10.99	10.98	10.71	11.54	14.27	10.24	10.61
4 13.96	13.57	11.38	12.82	12.93	13.54	11.83	11.87	11.62	12.22	13.22	11.24	11.57
5 13.60	14.42	12.47	13.65	13.53	13.63	13.29	13.21	12.65	13.19	13.40	12.27	12.59
Mean	13.90	12.77	10.57	11.37	13.61	11.27	10.90	10.75	11.63	13.69	10.20	10.54
DR-E												
DS 1	14.17	9.66	9.13	8.35	10.33	13.34	8.40	7.81	7.75	9.32	13.86	7.55
8.74												7.37
2 13.68	11.28	9.97	9.41	11.08	13.33	9.24	8.74	8.86	10.05	14.64	8.61	9.02
3 14.09	12.02	10.89	10.40	11.85	13.83	9.93	10.15	9.66	10.89	13.85	9.29	9.80
4 14.14	12.81	11.89	11.34	12.54	13.48	10.63	10.88	10.48	11.37	13.87	10.43	10.49
5 13.46	13.43	12.65	12.47	13.00	13.38	11.58	11.61	11.20	11.94	13.81	11.57	11.37
Mean	13.91	11.84	10.91	11.76	13.47	9.96	9.84	9.59	10.71	14.01	9.49	9.69
DS 1	14.05	10.37	9.33	8.71	10.62	13.53	9.11	8.19	8.29	9.78	13.88	7.48
8.98												7.37
2 13.97	11.58	9.54	9.75	11.21	13.51	9.84	9.31	9.40	10.51	14.15	8.88	9.37
3 13.93	12.46	10.61	10.82	11.96	13.65	10.46	10.57	10.18	11.22	14.06	9.76	10.20
4 14.05	13.19	11.64	12.08	12.74	13.51	11.23	11.37	11.05	11.79	13.54	10.83	11.03
5 13.53	13.92	12.56	13.06	13.27	13.51	12.44	12.41	11.92	12.57	13.61	11.92	11.98
Mean	13.91	12.31	10.74	10.88	13.54	10.61	10.37	10.17	11.57	12.27	12.23	11.47
For AFS												9.60
For comparison of												9.33
AFS												
DR												
DS												
AFS-DR												
AFS-DS												
DR-DS												
AFS-DR-DS												
For AFS												
For comparison of												
AFS												
DR												
DS												
AFS-DR												
AFS-DS												
DR-DS												
AFS-DR-DS												

AFS - Agroforestry systems, viz S-sole sorghum; S+T - sorghum +teak; S+T+G - sorghum + teak + grass; S+T+Sb - sorghum +teak+subabul

DR-W : Direction - western side of teak row, DR-E : direction - eastern side of teak row, DS - distance from teak row in metres (1-5)

effect.

REFERENCES

- Chauhan V K, Sood S K, Bhargava J A and Mishra V K. 1995. Effect of different trees on the yield of rainfed wheat crop. *Annals of Forestry* 3 (2):147-51.
- Ital C J. 1987, 'Investigation on agroforestry in northern dry zone of Karnataka'. Ph D thesis, University of Agricultural Sciences, Dharwad.
- Nadagoud V B. 1990, 'Performance of tree species and their influence on seasonal crops in agroforestry systems under irrigation'. PhD thesis, University of Agricultural Sciences, Dharwad.
- Roder W, Keoboualapha B and Manivanh V. 1995. Teak fruit, trees and other perennials used by hill farmers of northern Laos. *Agroforestry Systems* 29 (1) : 47-60.
- Sharma K K, Khanna A and Gulati A. 1996. Influence of eucalyptus shelterbelts on fodder crops. *Indian Forester* 122 (7): 655-64.

Phenotypic stability for seed yield in sesame (*Sesamum indicum*)

Z S SOLANKI¹, B S RAJPUROHIT² and DEEPAK GUPTA³

Agricultural Research Station, Rajasthan Agricultural University, Mandor, Jodhpur 342 304

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Key words: phenotypic stability, seed yield, sesame

In recent years the interest of the plant breeders has been directed towards better adaptation of the crop varieties. A desirable variety should have high stability of performance in terms of high seed yield. The study of genotype-environment interaction provides useful information to identify stable genotypes over range of environments. Hence an investigation was undertaken to study the G × E interaction and to identify both high yielding and stable genotypes over different years in Rajasthan.

The experimental material comprised seven released/advanced genotypes of sesame was grown in randomized block design with three replication over four environments during rainy season (*kharif*) 1994-97 at Mandor. Each plot consisted of 6 rows each 5 m long with a row to row spacing of 30 cm. Seed yield was recorded on plot basis and converted to kg/ha. The stability parameters of different varieties were computed on the basis of mean performance over years using statistical model suggested by Eberhart and Russell (1966).

Analysis of variance revealed that the environmental effect was highly significant indicating the different seasons influenced the performance of varieties (Table 1). The pooled analysis revealed significant differences among the varieties for seed yield indicating the presence of genetic variability among genotypes studied. Highly significant G × E interaction were obtained for seed yield, indicating that the genotypes interacted considerably with environmental conditions. Kumar (1988) reported similar results. Highly significant mean square due to environment (linear) for seed yield indicating considerable differences among environments. Both linear and non linear component of G×E interaction were also significant.

Mean seed yield ($\bar{X}$) and their two stability parameters, viz regression coefficient (b_i) and deviation from the regression (S^2_d) for seven genotypes are given in Table 2. Finley and Wilkinson (1963) considered linear regression as a measure of stability, whereas Eberhart and Russel (1966) emphasized that both linear (b_i) and non-linear (S^2_d) components of genotypes × environment interaction be

considered in judging stability of genotypes. Accordingly, the mean ($\bar{X}$) and deviation from regression (S^2_d) of each genotypes was considered for stability and linear regression (b_i) was used for testing the varietal response. Hence, an ideally adaptable variety would be the one having high mean values, unit regression coefficient ($b_i=1$) and deviation from regression as small as possible (S^2_d).

In the present study the magnitude of regression coefficient and deviation from regression varied from genotype to genotype. Out of seven genotype tested only four, viz 'RT 46', 'TC 25', 'RT 274' and 'RT 283' were found stable for seed yield over environments as indicated by their non-significant deviation from regression (S^2_d). Among these stable genotypes, 'RT 283' showed average response to change of environmental conditions as indicated by their regression coefficient (b_i) near to unity suggesting average stability and wide adaptability of this genotype. Whereas, two genotypes 'RT 46' and 'TC 25' were identified as suitable genotypes for unfavourable environments as indicated by their low b_i values (<1.0). On the other hand, significantly high regression coefficient value (>1.0) for 'RT 274' indicated its suitability for favourable environments. Among the stable genotypes 'RT 274' and 'RT 283' are advanced genotypes under pipeline whereas, 'RT 46' is a variety released for the cultivation in the state of Rajasthan, Harayana, Punjab and western Uttar Pradesh. The other genotypes 'RT 125', 'RT 242' and 'RT

Table 1 Pooled analysis of variance for different characters in sesame

Source of variation	DF	Seed yield
Genotype(G)	6	17768.2**+
Environment (E)	3	224889.2***++
Genotype x Environment	18	5155.7**
E + (G × E)	21	36546.2***++
Environment (linear)	1	674667.6***++
Genotype × Environment (linear)	6	3977.8**
Pooled deviation	14	4924.0**
Pooled error	56	885.9

** Significant at $P=0.10$ level against pooled error

Significant at* $P=0.05$ and** $P=0.10$

*Short note

¹Associate Professor (Plant Breeding & Genetics), ²Assistant Professor (Plant Breeding & Genetics), ³Technical Assistant

Table 2 Estimates of stability parameters of different characters in sesame

Genotype	Seed yield (kg /ha)		
	X-	bi	S ² d
'RT 46'	469.6	0.89	939.8
'RT 125'	487.6	1.16	4838.6**
'TC 25'	339.2	0.73	805.0
'RT 274'	542.4	1.10	351.0
'RT 242'	481.4	1.30	8192.0**
'RT 283'	533.6	1.01	121.7
'RT 282'	476.7	0.81	13018.8**
General mean	475.8		

'282' also recorded high mean seed yield but found to be unstable in their performance over environments as indicated by their significant deviation from regression (S^2d).

It can be concluded that the genotype 'RT 283' is ideal as

it has high mean seed yield, average response to change of environmental conditions and non-significant deviation from regression line. The genotype 'RT 274' had the highest seed yield performance and showed better performance under favourable environmental conditions while 'RT 46' was found suitable under unfavourable environmental conditions. Hence these two genotypes can be exploited for breeding high yielding varieties.

REFERENCES

- Eberhart S A and Russell W A. 1966. Stability parameters for comparing varieties. *Crop Science* 6 : 36-40.
- Finley K W and Wilkinson G N. 1963. The analysis of adaptation in plant breeding programme. *Australian Journal of Agriculture Research* 14 : 742-54.
- Kumar D. 1988. Phenotypic stability for quantitative traits of sesame under rainfed condition of arid environment. *Journal of Oilseeds Research* 5 (1): 8-122.

Root growth and nitrogen fixation activities of mungbean (*Phaseolus radiatus*) grown under elevated carbon dioxide*

A C SRIVASTAVA¹, MADAN PAL² and U K SENGUPTA³

Indian Agricultural Research Institute, New Delhi 110 012

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Key words: elevated CO₂, N₂ fixation, root growth, *Phaseolus radiatus*

As atmospheric carbondioxide (CO₂) concentration increase, alterations in the flux of carbon from plants to the soil will take place which will be accompanied by changes in the allocation of carbon to the different plant parts. Earlier studies reported greater root dry weight and higher root to shoot ratios at elevated atmospheric CO₂ concentration, which could be advantageous to plants for better growth. However, before this conclusion can be drawn, root system developed under elevated CO₂ need to be better described.

On the other hand, nitrogen limitation to production is a strong constraint on carbon storage in the biosphere. Bazaz (1990) has postulated that increased production under elevated CO₂ will diminish over time, as nitrogen becomes more limiting due to increased growth. In this context, the symbiotic interaction between legume and Rhizobium offer unlimited nitrogen source from the atmosphere to the host plant. Symbiotic nitrogen fixation in many legumes greatly stimulated under elevated CO₂ (Finn and Brun 1982) but the response of mungbean to elevated CO₂ has not been described. Hence, a study was conducted to determine nodulation and nitrogen fixation activities in mungbean under elevated CO₂ and to predict how mungbean will react to the future levels of atmospheric CO₂.

'PS 16' mungbean (*Phaseolus radiatus* L.) was grown in 14" pots at the Institute, New Delhi. Five plants were maintained in good quality soil in each pot after thinning. In the experiment a modified open top chamber (1.8 m × 1.6 m) as described by Rogers *et al.* (1983) was developed to study crop responses to elevated CO₂. One group of plants was grown under ambient CO₂ (350±25 ppm) and other group of plants was grown under elevated CO₂ (600±50 ppm). The concentration of CO₂ in the chamber was monitored through the suction pump of an IRGA (Licor 6200).

Plants were harvested at 30, 40 and 50 days after germination in bright and sunny days. At each harvest, roots were washed carefully to study the structure of the root system and the length of the main root was measured. Roots were

cut into pieces and dried in an oven at 80°C for 4 hr and then at 60°C till a constant weight recorded. Dry weight was recorded by electronic balance (Sartorius 1212 MP).

Total nitrogenase activity of the plants was assayed by the acetylene reduction techniques (Hardy *et al.* 1968). Nodulated root systems were uprooted, washed from the soil and incubated in the dark for 60 minutes in 500-ml plastic bottles with 10-cc acetylene. Ethylene production was measured on a Perkin Elmer Model 2000 gas chromatograph. An external ethylene standard was used. The nodules were removed from the root, dried at 70°C and weighed. The nitrogenase activity was expressed as nmoles of ethylene produced/hr and was calculated by the following formula

$$\text{N moles of C}_2\text{H}_4 \text{ produced} = \frac{\text{N moles of sample} \times \text{air space (ml)} \times \text{attenuation (sample)} \times 60 \times 1}{\text{Gas sample injected} \times \text{attenuation (std)} \times \text{in cubation time} \times \text{sample weight}}$$

Root growth and dry weight were substantially increased by elevated CO₂. The increase in root length due to elevated CO₂ was 28.69, 13.01 and 1.75% at 30, 40 and 50 days after germination respectively. Similar trends were obtained for root dry weight (Table 1). However, equal root dry weight was obtained at 50 days after germination. The comparison of partitioning of dry matter allocation to above and under ground portion showed that the shoot: root ratio of the plant decreased under high CO₂ concentrations. The results indicate that proportionate allocation of extra carbon fixed due to CO₂ enrichment was greater to the roots than to the shoots. This will provide the plants greater support for the growth under high CO₂ environments. Similar findings were obtained in other crop species in which greater amount of fixed extra carbon partitioned to the roots (Bazaz 1990). The present study also showed that there was not much change in root length individually but there was cumulative increase in root length as observed in soybean (Delcastillo *et al.* 1989). Thus, under high CO₂, plants will be made available to greater soil mass for higher moisture uptake. This may be one of the factors for better growth of the plants under high CO₂ conditions.

The higher CO₂ level brought a significant increase in

¹Research Associate, ²Scientist, ³Emeritus Scientist (CSIR), Plant Physiology, IARI

Table 1 The effects of CO₂ concentration on the growth and nodulation activity of mungbean at different growth stages

Growth stages	CO ₂ treatments (ppm)	Growth parameters			Nodule activity			Nitrogenase activity (nmoles C ₂ H ₄ /ha
		PDW	RWD	RWR	NDW	NWR	NN	
30 days	Ambient (350)	1.03	0.22	0.21	30	29.13	24.67	646.79
	Elevated (600)	2.22	0.46	0.21	80	36.04	46.67	851.28
	Percent change	115.53	109.09	0.00	166	23.72	89.18	31.62
40 Days	Ambient (350)	2.21	0.33	0.15	40	18.09	27.33	939.00
	Elevated (600)	3.9	1.11	0.28	90	23.08	57.00	1765.70
	Percent change	76.47	236.36	86.67	125	27.58	108.56	88.04
50 days	Ambient (350)	3.73	1.12	0.30	80	21.45	43.00	635.01
	Elevated (600)	4.3	1.11	0.26	110	25.58	63.00	666.40
	Percent change	15.28	-0.89	-13.33	37.50	19.25	46.51	4.94

PDW, Plant dry weight (g); RDW, root dry weight (g); RWR, root weight ratio; NDW, nodule dry weight (mg); NWR, nodule weight ratio; NN, nodule number

nodule number and nodule dry weight at all growth stages (Table 1). Total nitrogenase activity (acetylene reduction assay) of mungbean was increased by CO₂ enrichment at all growth stages but the major increase was observed at 40 days after germination (Table 1). Elevated CO₂ presumably increased plant growth, nodulation and nitrogenase activity either directly or indirectly by increasing the rate of photosynthesis (Oehel and Strain 1985).

The link between carbon and nitrogen fixation in this experiment was manifested primarily through nodulation or nodule development. The greater nodule weight under elevated CO₂ can be attributed primarily to their larger root systems, which provided more sites for nodule establishment. Alternatively, greater nodule mass in CO₂ enriched plants could have been a response to increased internal nitrogen demand in these plants (Tjepkema *et al.* 1986) brought on by their faster growth rate relative to seedlings in ambient CO₂. It was observed that the increase in nodulation exceeded the increase in plant dry weight (greater nodule weight ratio), even though root weight ratio was unaffected by elevated CO₂. Enriched CO₂ may have stimulated other mechanisms involved in nodule establishment, such as the synthesis, translocation or exudation of organic compounds that stimulate bacterial proliferation in the rhizosphere or infection of the root.

These studies demonstrate that significant growth responses to CO₂ enrichment can occur in mungbean in nutrient limited conditions due to increase in nodulation and nitrogenase activity which can ultimately lead to an increase in nutrient availability and support the growth.

In nutshell, nodulation, nitrogenase activity and root

growth of 'PS 16' mungbean substantially increase in elevated CO₂ grown plants. Significant increase in root length and root dry matter occurred with CO₂ enrichment despite low nitrogen content which support the premise that in legumes stimulation of symbiotic activity by CO₂ enrichment could help in increasing plant growth.

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REFERENCES

- Bazaz F A. 1990. The response of natural ecosystems to the rising CO₂ levels. *Annual Review of Ecological System* 21 : 167-96.
- Delcastillo D, Acock B, Reddy V R and Acock M C. 1989. Elongation and branching of roots on soybean plants in a CO₂ enriched aerial environment. *Agronomy Journal* 81 : 692-5.
- Finn G A and Brun W A. 1982. Effect of atmospheric CO₂ enrichment on growth, non-structural carbohydrate content and root nodule activity in soybean. *Plant Physiology* 69 : 327-31.
- Hordy R W F, Holsten R D, Jackson E K and Burns R C. 1968. The acetylene reduction assay for nitrogen fixation : Laboratory and field evaluation. *Plant Physiology* 43 : 1195-1207
- Oehel W C and Strain B R. 1985. Native species responses to increased atmospheric CO₂ concentration. (in) *Direct Effects of Increasing CO₂ on Vegetation*, pp 117-54, Strain B R and Cure J D (Eds) DOEIR-0238, USD, Washington, DC.
- Rogers H H, Heck W W and Heagle A S. 1983a. A field techniques for the study of plant responses to elevated CO₂ concentration. *Air Pollution Control Association Journal* 92 : 144.
- Tjepkema J D, Schwintzer C R and Benson D R. 1986. Physiology of actinorhizal nodules. *Annual Review of Plant Physiology* 37 : 209-32.

Temperature and precipitation effects on grain yield of finger millet (*Eleusine coracana*) genotypes at high hills of Garhwal Himalayas*

B B BANDYOPADHYAY¹

Govind Ballabh Pant University of Agriculture and Technology, Hill Campus, Ranichauri, Tehri Garhwal, Uttar Pradesh 249 199

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Key words: finger millet, grain yield, high altitude, temperature, precipitation

Finger millet (*Eleusine coracana* (L.) Gaertn) is cultivated in India under rainfed condition up to 3000 m altitude at hills in the Himalayas (Doggett 1986). It favours warm climatic condition for better expression of characters and effective seed production. At hills in the Himalayas, finger millet genotypes gives poor grain yield, much below the national average, perhaps due to exposure to sub optimum temperature, changes in elevation, variation in local air temperature and precipitation. The low temperature exerts its effect on reduction of photosynthetic activities and translocation of photosynthates from leaves (Ishikawa *et al.* 1994, Akita 1995). Hilliard and West (1970) reported that in some tropical species at an exposure to less than 20°C night temperature, the cultivars were unable to roll back their normal physiological activities in the following day even though the day temperature was recorded high. In order to understand whether the loss in grain yield of finger millets at high hills was primarily associated with poor seed set from early stress in growing season or with late abiotic stress, the impact of temperature and precipitation effect was examined under rainfed condition in the present investigation for developing suitable high yielding cultivars for high hills of Garhwal Himalayas.

The performance of 257 finger millet genotypes was studied at high hills (2100 m above mean sea-level) of Garhwal at Ranichauri (30° 15' N and 78° 02' E) under low atmospheric temperature and rainfed condition during 1994–98. In each year, seeds of 50 entries on average were sown during *kharif* rainy season in June. The experiment was laid out in a randomized block design with 3 replications. Plot size was 3 m × 1 m and the spacing between plants and rows were maintained at 10 and 25 cm respectively. Recommended agronomic package of practices were followed. Observations were recorded on days to 50% head emergence, days to maturity and grain yield. The time interval between date of sowing to date of 50% head emergence and from date of 50% head emergence to date of maturity were considered as

pre-and post flowering stage of crop growth respectively. Temperature and precipitation data were collected from meteorological department of the University, Ranichauri Campus. The total rainfall, number of days of rain, and the cumulative values of daily maximum and minimum air temperature (thermal time, expressed in degree days) were estimated at pre- and post flowering period of crop growth. The monthly average temperature for day and night (ie maximum day and minimum night temperature) was worked out by dividing the cumulative values of temperature by number of days for each year separately. As the mean value of daily atmospheric temperature at high hills over 5 years hardly exceeded 20°C during entire growing season particularly at effective period of grain growth, the thermal times (degree days) for this investigation were considered at day, night and mean daily air temperature, in place of daily average air temperature. Correlation and regression analysis were worked out on mean data of each genotype of finger millet and relevant meteorological data on respective years. Characters exhibiting significant association with grain yield were only considered for regression analysis.

Mean values of meteorological data (Table 1) revealed that adequate rainfall and number of rainy days were experienced during pre-flowering period of crop growth. Ambient atmosphere, however, remained cool as indicated by prolong vegetative period of cultivars and late emergence of head. Air temperature at experimental site started declining from 3rd week of August which was considered to be an effective period of grain growth. An exposure to low atmospheric temperature under field condition, therefore, favoured a prolonged duration of grain growth (Chowdhury and Wardlaw 1978) at high altitude among finger millet genotypes. It was assumed that sensitivity of crop to low night temperature and accumulation of high starch content on leaves perhaps associated with cessation of normal physiological activities below 20°C (Hilliard and West 1970, Evans and Bush 1985) and led to constitute a great loss in grain production of finger millet genotypes at hills in the Himalayas.

Cumulative temperatures (ie thermal times) and

* Short note

¹Junior Research Officer

Table 1 Meteorological data on mean temperature ($^{\circ}\text{C}$), precipitation (mm) and number of rainy days at experimental site (2100 m above mean sea level of Gathwal Himalayas) for the year 1994-98 during growing season of finger millets

Month	Days	1994			1995			1996			1997			1998			
		Day	Night	Mean	Day	Night	Mean	Day	Night	Mean	Day	Night	Mean	Day	Night	Mean	
May	1-15	23.78	12.26	18.02	26.04	14.21	20.12	25.81	11.83	18.82	21.56	10.19	15.87	23.51	12.46	17.98	
	16-31	25.91	15.30	20.60	27.73	15.48	21.60	26.49	12.40	19.44	25.29	12.98	19.13	27.43	17.36	22.39	
	1-31	24.84	13.78	19.31	26.88	14.84	20.86	26.15	12.11	19.13	23.42	11.58	17.50	25.47	14.91	20.18	
June	1-15	27.64	16.36	22.00	30.18	18.74	24.66	25.72	13.28	19.50	23.96	13.08	18.52	27.12	16.39	21.75	
	16-31	24.94	18.24	21.59	24.56	15.48	20.02	24.02	15.00	19.51	24.42	15.18	19.80	24.72	18.05	21.38	
	1-31	26.29	17.30	21.79	27.37	17.11	22.24	24.87	14.14	19.50	24.19	14.13	19.16	25.92	17.22	21.57	
July	1-15	23.84	17.42	20.63	23.02	16.73	19.87	22.69	14.94	18.81	22.96	17.22	20.09	23.23	17.68	20.45	
	16-31	22.68	17.73	20.20	22.82	16.42	19.62	23.05	15.61	19.33	23.18	17.13	20.15	23.24	17.48	20.36	
	1-31	23.26	17.57	20.41	22.92	16.57	19.74	22.87	15.27	19.07	23.07	17.17	20.12	23.23	17.58	20.40	
August	1-15	23.42	17.64	20.53	22.58	16.36	19.47	22.48	15.51	18.99	22.06	16.10	19.08	22.64	17.68	20.16	
	16-31	21.88	16.99	19.43	21.79	15.72	18.75	21.67	14.37	18.02	22.95	16.25	19.60	21.81	16.79	19.30	
	1-31	22.65	17.30	19.98	22.18	16.04	19.11	22.07	14.94	18.50	22.50	16.17	19.33	22.20	17.23	19.72	
September	1-15	22.98	16.60	19.79	23.03	14.44	18.73	21.29	13.84	17.55	21.24	15.30	18.27	23.18	15.50	19.34	
	16-30	22.37	14.24	18.30	22.52	13.78	18.15	20.89	12.38	16.63	21.56	13.73	17.64	21.52	15.31	18.41	
	1-30	22.67	15.42	19.04	22.77	14.11	18.44	21.08	13.11	17.09	21.40	14.51	17.95	22.35	15.40	18.87	
October	1-15	21.33	12.63	16.98	21.30	11.82	16.56	20.30	8.98	14.64	18.29	9.63	13.96	21.82	13.08	17.45	
	16-31	19.21	9.20	14.20	19.89	8.53	14.21	19.13	8.83	14.00	16.25	8.57	12.41	18.30	10.40	14.60	
	1-31	20.27	10.91	15.59	20.59	10.17	15.38	19.71	8.93	14.32	17.27	9.10	13.18	20.31	11.74	16.02	
															Average over 5 years		
		Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day		
May		85.1	12		22.3	5		70.6	11		65.8	5		50.34	7.2		
June		77.9	12		104.2	14		137.3	15		150.1	9		119.74	11.8		
July		412.6	25		225.6	15		117.5	15		290.2	19		279.42	18.8		
August		313.2	21		282.0	23		332.6	17		430.7	25		344.34	21.8		
Sept		61.2	6		144.0	14		180.2	12		134.5	12		147.54	10.6		
October		0	0		65.2	4		44.1	11		331.0	4		88.7	4.2		

Table 2 Estimates of correlation coefficient values and regression equation among some agronomic important characters, air temperature (day, night and mean thermal time) and precipitation (rainfall and number of rainy days) data

	RD-1	DT-1	NT-1	MT-1	DH	RF-2#	RD-2#	DT-2	NT-2	MT-2	DM	GY
RF-1#	0.418**	0.211**	0.345**	0.277**	0.124*	-0.085	-0.375**	-0.010	0.105	0.099	-0.074	0.081
RD-1		0.694**	0.631**	0.646**	0.649**	-0.463**	-0.681**	-0.288**	-0.238**	-0.147**	-0.248**	-0.224**
DT-1			0.946**	0.941**	0.902**	-0.125*	-0.385**	-0.658**	-0.387**	-0.359**	-0.625**	-0.481**
NT-1				0.938**	0.814**	-0.044	-0.349**	-0.648**	-0.342**	-0.345**	-0.633**	-0.440**
MT-1					0.831**	-0.089	-0.363**	-0.654**	-0.358**	-0.351**	-0.633**	-0.451**
DH						-0.261**	-0.402**	-0.660**	-0.388**	-0.352**	-0.652**	-0.449**
RF-2#							0.543**	0.285**	0.181**	0.089	0.247**	0.104
RD-2#								0.246**	0.155**	0.078	0.247**	0.104
DT-2									0.458**	0.466**	0.984**	0.404**
NT-2										0.109	0.429**	0.239**
MT-2											0.448**	0.287**
DM												0.328**

Regression equation:

$$Y = (20.01858) + (0.10867) x_1 + (-0.00060) x_2 + (-0.00569) x_3 + (-0.00147) x_4 + (-0.00210) x_5 + (-0.86530**) x_6 + (0.04199**) x_7 + (-0.00001) x_8 + (0.00104) x_9$$

Residual effect (R^2) = 0.37452

where: y = Grain yield (GY); x_1 , number of rainy days at pre flowering period (RD-1); x_2 , days to 50% head emergence (DH); x_3 , thermal time for day temperature at pre-flowering period (DT-1); x_4 , thermal time for night temperature at pre-flowering period (NT-1); x_5 , thermal time for mean daily temperature at pre-flowering period (MT-1); x_6 , days to maturity (DM); x_7 , thermal time for day temperature at post-flowering period (DT-2); x_8 , thermal time for night temperature at post-flowering period (NT-2); x_9 , thermal time for mean daily temperature at post-flowering period (MT-2); *, ** significant at $P=0.05$ and $P=0.01$ level of probability; RF1# = total volume of rainfall at pre-flowering period (RF-1); RF-2# = total volume of rainfall at post-flowering period (RF-2) and RD-2# = number of rainy days at post-flowering period (RD-2)

precipitation at pre-flowering period registered significant positive association among themselves and with days to 50% head emergence, while the influence of temperature and the number of rainy days at pre-flowering stages constituted negative significant association with grain yield, days to maturity, thermal times for maturity and precipitation received at post-flowering period (Table 2). An increase in total rainfall and number of rainy days at pre-flowering period brought down the air temperature which in turn increased the degree days for 50% head emergence and the number of days required for 50% heading among finger millet genotypes while decreased the physiological production capacity of cultivars by subsequent reduction in thermal times for effective grain growth and days to maturity as well. The number of rainy days at pre-flowering period rather than total amount of rainfall received during the vegetative period of crop growth had inversely affected grain production of finger millet at high altitude in the Himalayas. Thermal time at post-flowering period showed significant positive correlation with both days to maturity and grain yield. The results suggested that greater degree days for effective grain growth were required for higher grain yields.

The thermal time for average air temperature at post-flowering period showed non-significant association with low night temperature during later part of crop development. This suggested that consideration of mean daily temperature at post-flowering period would be ineffective in delineating variation in low night temperature at hills in the Himalayas during effective period of grain growth among finger millet genotypes.

Regression analysis (Table 2) revealed that days to maturity and thermal time for day temperature at post-flowering period registered significant negative and positive regression coefficient value respectively on grain yield. This indicated that grain production of finger millet genotypes were largely depended upon greater degree days for day temperature during effective grain growth and on early maturity. The results of correlation study, however, indicated that high degree days

for day temperature during grain growth imposed restrictions on hastening the maturity. It was, therefore, assumed that the genotypes of finger millet were exposed to sub-optimum temperature for grain development and maturity at high hills during post-flowering period and the limitation in physiological activities perhaps involved in constituting these relationships and produced poor grain yield at an exposure to cool climatic condition of Garhwal Hills at high altitude in the Himalayas.

Regression analysis indicated that only 62.55% variability in grain production of finger millet could be explained through temperature and precipitation effect at high hills in Garhwal Himalayas, while 37.45% remained unexplained. It was, therefore, evident that temperature and rainfall are not the only two components influencing the yield variation. Incorporation of other factors are required for the study to account fully for the variation in yield of finger millet at high altitude.

REFERENCES

- Akita S. 1995. Ecophysiological aspects of increasing the biological and commercial yield potential of rice (*Oryza sativa* L.). *International Rice Commission New Letter*, FAO 44 : 21-32.
- Chowdhury S. I and Wardlaw I F. 1978. The effect of temperature on kernel development in cereals. *Australian Journal of Agricultural Research* 29 : 205-23.
- Doggett H. 1989. Small millets - a selective review, pp 3-17 (in) *Small Millet in Global Agriculture*, Seetharam A. (Ed) Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Evans L T and Bush M G. 1985. Growth and development of channel millet (*Echinochloa turneriana*) in relation to its potential as a crop plant and compared with other *Echinochloa* millets, rice and wheat. *Field crops Research* 12 : 1 231-5.
- Hilliard J H and West S H. 1970. Starch accumulation associated with growth reduction at low temperature in tropical species. *Science* 168 : 494-6.
- Ishikawa T, Hoshina T, Nagata K, Nakamura I, Akita S and Kabaki N. 1994. Effect of temperature during reproductive period on spikelet numbers in rice (*Oryza sativa* L.). *Japanese Journal of Crop Science* 63 (Extra issue) (1) : 152-3.

Genetic architecture of oil content over environments in castor (*Ricinus communis*)*

S S SOLANKI¹ and P JOSHI²

Agricultural Research Station, Rajasthan Agricultural university, Mandor, Jodhpur 342 304

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Key words: castor, genotype × environment interaction, gene effects, combining ability, oil content

India is a principal castor (*Ricinus communis* L.) growing country of the world. Castor is a non-edible oil crop having much economic significance because of its great export demands. Castor oil is an unique industrial oil due to presence of high content of fatty acid ricinoleic acid, which is synthesized only in castor. The main uses of oil are in the dehydrated form for paint, varnish and other protective coatings. The oil and its derivatives are used in lubricants, hydraulic fluid, soap, printing ink, linoleum and in the production of sebacic acid and undecylenic acid are used in plasticized and nylon. Besides these it also used in medicine, cosmetic and polishes, etc.

Oil content in castor seeds ranges from 35–59 % with 80–95 % ricinoleic acid (Yadav *et al.* 2000). Seed yield and oil content are also influenced by environments. Thus in the present study, 28 castor hybrid and 8 parents were evaluated in different environments over 2 years to understand the inheritance of oil content.

The eight diverse parents, viz VP I, MCP I, MCP 2 and 240 (pistillate lines) RG 184 (monoecious), RG 125, RG 299 and 846 (mostly male) were crossed in diallel mating design (excluding reciprocals). Parents and their 28 crosses were grown in six environments over two seasons in 2 years (1993–94 and 1994–95). The environments were created by dates of sowing, ie 15 July, 30 July and 15 August. The experiments were laid out in randomised block design with 3 replications. In each replication parents and crosses were randomized separately. Each genotype consisting of 2 rows spaced planted and seeding rate was 1 seed/60 cm in rows spaced at 90 cm part. Recommended packages of practices for irrigated condition was adopted to raise the crop. In each treatment three bulk samples were used for recording the oil content. Per cent oil content was estimated with the help of nuclear magnetic resonance. The seed samples were oven

dried at 110°C for 24 hr and observation on per cent oil content was recorded. The mean values were subjected to the statistical analysis and combining ability analysis was computed on the data obtained (pooled over environments) for parents and F₁ using method 2, model 1 of Griffing (1956) and Singh (1973 and 1979).

The analysis of variance for the experimental design revealed significant mean sum of squares due to genotypes and its subdivisions (parents, hybrids and parents vs hybrids) for oil content. It indicated the presence of sufficient variability in material under experimentation. Highly significant variance due to environment for this trait indicated differences in the environments created for the study. Significant genotype × environment interaction revealed that expression of different genotypes was influenced by the environments. Further partitioning of the G × E interaction into parents × environments and hybrids × environments showed higher magnitude of hybrids × environments interaction.

Combining ability analysis indicated highly significant mean squares due to general combining ability and specific combining ability (Table 1). It revealed the importance of

Table 1 Combining ability analysis estimates over environments for oil content in castor

Source	DF	Mean sum of squares
GCA	7	6.53**
SCA	28	1.60**
Environments	5	0.12**
GCA×Environment	35	0.19**
SCA×Environment	140	0.22**
Error	420	0.09
<i>Estimates</i>		
σ^2_{gca}		0.11
σ^2_{sca}		0.22
$\sigma^2_{gca} / \sigma^2_{gca} \times 1$		11.00
$\sigma^2_{sca} / \sigma^2_{sca} \times 1$		1.69

** Significant at $P=0.01$

* Short note

Based on a part of the Ph D thesis submitted to the Rajasthan Agricultural University, Bikaner during 1998

¹Assistant Professor, Department of Plant Breeding and Genetics

²Dean, SKN College of Agriculture, Jobner, Jaipur (Rajasthan)

Table 2 Estimates of general combining ability, specific combining ability effects and *per se* for oil content over environments in castor

Parents/Crosses	gca/sca effects	Oil content
VP1	-0.15**	47.94
MCP1	-0.15**	48.29
MCP2	0.004	48.20
240	-0.04	47.66
RG184	-0.45**	47.39
RG125	0.71**	49.68
RG299	0.08*	48.08
846	-0.001	47.98
VP1×MCP1	-0.31**	47.81
VP1×MCP2	0.08	48.36
VP1×240	0.77**	49.00
VP1×RG184	-0.34**	47.49
VP1×RG125	0.57**	49.56
VP1×RG299	-0.10	48.26
VP1×846	-0.41**	47.86
MCP1×MCP2	-0.35**	47.92
MCP1×240	-0.43**	47.80
MCP1×RG184	-0.28**	47.55
MCP1×RG125	0.73**	49.72
MCP1×RG299	-0.17**	48.18
MCP1×846	0.47**	48.74
MCP2×240	-0.41**	47.98
MCP2×RG184	0.30**	48.28
MCP2×RG125	0.58**	49.73
MCP2×RG299	-0.22	48.30
MCP2×846	0.50**	48.93
240×RG184	0.47**	48.41
240×RG125	0.05*	49.15
240×RG299	0.31**	48.78
240×846	0.62**	49.01
RG184×RG125	-0.44**	48.24
RG184×RG299	0.49**	48.56
RG184×846	0.06	48.04
RG125×RG299	-0.04	49.17
RG125×846	-1.12**	48.01
RG299×846	0.76**	49.27

SE_g 0.03, SE_{s_j} 0.11, **significant at $P=0.01$, *significant at $P=0.05$

additive and non-additive gene effects for the expression of oil content. Significant GCA × environment and SCA × env. interaction indicated the importance of experimentation over environments to assess the genetic worth of the genotypes. The lower estimates of σ^2_{sca} σ^2_{sl} as compared to σ^2_{gca} σ^2_{gl} for this trait indicated that non-additive gene effects were susceptible to the environmental changes as compared to additive effects. The higher magnitude of σ^2_{sca} in comparison to σ^2_{gca} indicated the preponderance of non-additive gene effects in the inheritance of oil content. The preponderance of non-additive gene effects in the inheritance of oil content has also been reported by Patel (1991), Saiyed (1992) and Patel (1994). Contrary to this Giriraj *et al.*

(1973) had reported that, inheritance of oil content is mainly governed by additive gene effects, such differences might be due to material, genetic model used or conduct of experiment under single environment.

The estimates of gca effects for oil content were significant for five parents, maximum being in RG 125 (0.71) and minimum in RG 184 and none of the pistillate lines was found to be good combiner for this trait (Table 2). It emphasized the need for initiating breeding programme for the improvement of oil content in pistillate lines. The male parent RG 125 exhibiting high maleness was the best general combiner for oil content. In addition to high gca effects, RG 125 also recorded the highest *per se* oil content (49.7%). In general *per se* performance of parents was in agreement with their gca effects. The male parent RG 125 which had high maleness was a good combiner for earliness and 100 seed weight (Solanki 1998), the parent possessing additive effects for these important traits is highly desirable for breeding programmes.

The specific combining ability effects for oil content were significantly positive in twelve crosses. The magnitude of sca effects was maximum in cross VP¹ × 240 followed by cross RG 299 × 846 and MCP 1 × RG 125. Usually the crosses found superior in *per se* performance depicted significant positive sca effects. Amongst the crosses exhibiting significantly positive sca effects crosses MCP1 × RG 125, MCP 2 × RG 125, VP 1 × RG 125, RG 299 × 846 and RG 184 × RG 299 were combination of low × high or high × low general combiners. In these crosses dominance type of gene action was responsible for expression of oil content. Remaining crosses ie VP 1 × 240, 240 × 846, MCP 2 × 846, 240 × RG 299, MCP¹ × 846, 240 × RG 184 and MCP 2 × RG 184 were combination of low × low general combiners. It indicated predominant role of epistatic type of gene action for the inheritance of oil content in these crosses. Based on present finding it could be concluded that dominance and epistatic type of gene actions were responsible for expression of oil content in crosses exhibiting desirable sca effects.

Oil yield is the function of per cent oil content and seed yield. The seed yield depends upon various yield contributing characters. Thus under present investigation superior crosses were identified considering *per se* for oil content, sca effects, oil yield and other component characters (earliness). Based on these criteria, the best cross identified was VP¹ × RG 125 since it registered high oil yield (156g/plant) and earliness for the emergence of primary raceme (10.7 nodes up to primary raceme). Other promising crosses on the basis of high oil yield were MCP 2 × RG 184 (157g/plant) and MCP¹ × RG 125 (152 g/plant), however these crosses recorded higher number of nodes to emergence of primary raceme. Castor is a cross pollinated crop in which hybrid vigour for seed yield and oil yield/oil content could be easily exploited through heterosis breeding. Segregating generations of superior crosses could also be handled for

isolating genotype having early/medium maturity and high oil yield/oil content. Further perusal of *per se* performance of parents and crosses for oil yield, seed yield and other yield contributing characters indicated that besides the per cent oil content other decisive factors contributing indirectly towards oil yield are seed yield and its component traits like 100-seed weight, spikes/plant and capsules/spike.

Based on present investigation it could be concluded that, the superior crosses involving pistillate $\times$ male parent can be directly utilised as the F_1 hybrids. Improvement of quality traits in castor can be achieved by increasing per cent oil content as well as the improvement of seed yield and its related components. The preponderance of non-additive gene effects for the expression of the oil content indicated that improvement of the quality trait could be achieved by adopting reciprocal recurrent selection.

REFERENCES

- Giriraj K Mensenkai and Sindgi S S. 1973. Combining ability of some quantitative characters in 6×6 diallel crosses of castor (*Ricinus communis* L). *Indian Journal of Agricultural Sciences* 43 (3) : 319-22.
- Griffing B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences* 9 : 463-93.
- Moshkin V A. 1986. *Castor*: Oxonian Press Pvt Ltd, New Delhi.
- Patel B N. 1994. 'Line $\times$ tester analysis over environments in castor (*Ricinus communis* L).' Ph D thesis, Gujarat Agricultural University, S'K Nagar.
- Patel N H. 1991. 'Genetic analysis of yield and its components in castor (*Ricinus communis* L).' Ph D thesis, Rajasthan Agricultural University, Bikaner.
- Saiyed M P. 1992. 'Studies on heterosis, combining ability analysis in castor (*Ricinus communis* L).' Ph D thesis, Gujarat Agricultural University, S K Nagar.
- Singh D. 1973. Diallel analysis for combining ability over environments - II. *Indian Journal of Genetics* 33 (3) : 469-81.
- Singh D. 1979 Diallel analysis for combining ability over environments. *Indian Journal of Genetics* 39 (3) : 383-6.
- Solanki S S. 1998. 'Genetic studies in castor.' Ph D thesis, Rajasthan Agricultural University, Bikaner.
- Yadav S K, Reddy P R and Vanaja M. 2000. Castor : A potential crop for diversified commercialization. *Extended Summaries. 2000. National Seminar on Oilseeds and Oils-Research and Development Needs in the Millennium*, held during 2-4 February 2000 at Indian Society of Oilseeds Research, DOR, Hyderabad, p 34.

Biological activity of four geographic isolates of baculovirus on groundnut redhairy caterpillar, *Amsacta albistriga* (Lepidoptera : Arctiidae)*

R K MURALI BASKARAN¹, T R SRINIVASAN², K MUTHUMEENA³,
S MUTHULAKSHMI⁴ and N R MAHADEVAN⁵

Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu 625 104

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Key words: *Amsacta albistriga*, NPV, geographic isolates, LC_{50} , LT_{50}

Redhairy caterpillar, (*Amsacta albistriga* Walker) is a seasonal but destructive polyphagous pests attacking several crops including rain fed groundnut (*Arachis hypogaea* L.) (David and Kumaraswami 1982). Entomopathogenic viruses, particularly the nuclear polyhedrosis virus is reported to be potential bio-pesticide for the management of this pest (Jayaraj and Rabindra 1989). However, their relatively slow action, specificity to a single insect pest, high level of ultraviolet inactivation as well as inactivation by glandular secretion of leaves and poor storage capability limit their efficacy and large scale commercial production and use. The undesirable qualities of nuclear polyhedrosis virus can be overcome by one of the ways to search in nature for new virus strains (Rabindra 1992). Viruses from members of the same host species from different geographical locations show variability in virulence and biological characteristics (Brown 1982). Field isolates of nuclear polyhedrosis virus collected in diverse geographic locations differ in their efficacy, reported on several pests including *A. albistriga* (Rabindra 1999), *Helicoverpa armigera* (Hubner) (Battu and Arora 1996; Ramesh Arora *et al.* 1997), etc. Hence, the present study was undertaken to evaluate four isolates of nuclear polyhedrosis virus of *A. albistriga* collected from Karnataka and Tamil Nadu States under laboratory condition.

Four isolates of nuclear polyhedrosis virus were obtained from naturally diseased *Amsacta albistriga* larvae from Dharwad and Pavagada (Karnataka) and Madurai and Narikudi (Tamil Nadu) during survey on rainfed groundnut from May to July 1999. The isolates thus collected were purified and amplified on fourth instar larvae of *A. albistriga* under laboratory condition. Each isolate was diluted serially ($1 \times 10^{2-8}$ polyhedral occlusion bodies/ml) in distilled water mixed with 0.1% teepol and bio-assayed with II, III and IV instar of *A. albistriga* through NPV treated groundnut leaves. Different instars of *A. albistriga* collected from rainfed

groundnut in Alagarkoil village were utilized for conducting experiments and each treatment was replicated thrice. The experiments were conducted at 33.6°C and 53.7% relative humidity during August 1999. The virus induced mortality was recorded daily starting from 4th day to 12th day. Variation in virulence of isolates of nuclear polyhedrosis virus obtained from different locations was measured by calculating LC_{50} and LT_{50} from the data thus obtained (Finney 1971). Finally, relative activity was calculated (Shapiro and Robertson 1992).

Biological activity (LC_{50} and LT_{50}) of four geographic isolates of nuclear polyhedrosis virus of *Amsacta albistriga* under laboratory condition revealed that Dharwad isolate collected from Karnataka State was more effective against II, III and IV instar of *A. albistriga*, followed by the isolates of Madurai and Narikudi (Tamil Nadu) and Pavagada (Karnataka). LC_{50} for Dharwad isolate was lowest at the concentration of 1×10^8 POBs/ml against II, III and IV instar of *A. albistriga* which was reduced by 5.70, 8.35 and 5.59 folds to 7.413×10^2 , 9.120×10^3 and 4.862×10^4 POBs/ml respectively while it was 3.889×10^3 , 7.143×10^4 and 2.660×10^5 POBs/ml for Madurai isolate, 3.954×10^3 , 7.533×10^4 and 2.685×10^5 POBs/ml for Narikudi isolate and 4.038×10^3 , 7.618×10^4 and 2.718×10^5 POBs/ml for Pavagada isolate (Table 1). Similarly, LT_{50} of Dharwad isolate was reduced by 1.37, 4.43 and 1.55 folds to 105.36, 113.52 and 122.16 h against II, III and IV instar of *A. albistriga* respectively (Table 2) while it was highest in Pavagada isolate (144.48, 162.72 and 189.84). Madurai and Narikudi isolate did not differ themselves, recording LT_{50} of 121.68, 148.08 and 163.44 h and 122.88, 158.72 and 167.52 h against II, III and IV instar of *A. albistriga* respectively at the concentration of 1×10^8 POBs/ml (Table 2).

The order of activity of four isolates of NPV against II, III and IV instar of *A. albistriga* was Dharwad > Madurai > Narikudi > Pavagada. Rabindra (1992) reported that an isolate of NPV of *H. armigera* obtained from the Nilgiris recorded the lower LC_{50} than those collected from Uthagamandalam, Aruppukottai and Gujarat. Odak (1982)

*Short note

^{1,2} Assistant Professor, ^{3,4} Research Fellow, ⁵ Professor and Head, Department of Agricultural Entomology

Table 1 LC_{50} and relative activity of different concentrations of four isolates of NPV against second, third and fourth instar of *Amsacta albistriga*

Instar	Isolate ^a	LC_{50} (POBs/ml)	Fiducial limits (POBs/ml)	Relative ^b activity
II	Madurai	3,889	1 202 – 12 589	1.04
	Dharwad	708	158 – 3 162	5.70
	Pavagada	4,038	1 375 – 12 985	1.00
	Narikudi	3,954	1 294 – 12 812	1.02
III	Madurai	74,131	21 878 – 2 51 189	1.03
	Dharwad	9,120	1 660 – 50 119	8.35
	Pavagada	76,187	22 055 – 2 63 538	1.00
	Narikudi	75,328	21 932 – 2 55 341	1.01
IV	Madurai	2,66,072	1 56 386 – 4 52 682	1.02
	Dharwad	48,621	7 029 – 3 36 372	5.59
	Pavagada	2,71,818	1 58 580 – 4 58 458	1.00
	Narikudi	2,68,583	1 57 051 – 4 56 001	1.01

^a Treatment involving NPV contained $1 \times 10^{2.8}$ POBs/ml, ^b Ratio of LC_{50} , where activity of Pavagada isolate equals 1.00

Table 2 LT_{50} and relative activity of different concentrations of four isolates of NPV against second, third and fourth instar of *Amsacta albistriga*

Instar	Isolate ^a	LT_{50} (h)	Fiducial limits (h)	Relative ^b activity
II	Madurai	121.68	113.04 – 130.80	1.19
	Dharwad	105.36	79.44 – 119.52	1.37
	Pavagada	144.48	125.76 – 158.16	1.00
	Narikudi	122.88	117.12 – 132.72	1.17
III	Madurai	148.08	141.36 – 154.80	1.09
	Dharwad	113.52	82.08 – 120.72	1.43
	Pavagada	162.72	144.48 – 168.24	1.00
	Narikudi	156.72	143.76 – 158.16	1.04
IV	Madurai	163.44	148.32 – 177.60	1.16
	Dharwad	122.16	102.00 – 146.16	1.55
	Pavagada	189.84	167.52 – 193.30	1.00
	Narikudi	167.52	156.24 – 189.12	1.13

^a Treatment involving NPV contained 1×10^8 POBs/ml, ^b ratio of LT_{50} , where activity of Pavagada isolate equals to 1.00

and Ramesh Arora *et al.* (1997) reported wide variations in the virulence and genetic make up of NPV of *H. armigera* collected from different agroclimatic regions of Punjab. However in case of NPV of *A. albistriga*, it was reported that there was no difference in restriction pattern of isolates collected from Coimbatore, Madurai, Kancheepuram and Hyderabad (Rabindra 1999). In the present study, similar results were obtained in which isolates collected from Madurai, Narikudi and Pavagada were more or less similar in their biological activity while Dharwad isolate was superior to all.

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REFERENCES

- Battu G S and Arora R. 1996. Genetic diversity of baculoviruses ; Implications in insect pest management, (in) *Biotechnological Perspectives in Chemical Ecology of Insects*, pp 170–200 T N Ananthakrishnan (Ed), Oxford and IBH Co, New Delhi.
- Brown D A. 1982. Two naturally occurring nuclear polyhedrosis variants of *Neodiprion sertifer* (Hymenoptera : Diprionidae). *Applied Environmental Microbiology* 43 : 65–9.
- David B V and Kumaraswami T. 1982. *Elements of Economic Entomology*, pp 536 Popular Book Depot, Madras.
- Finney D J. 1971. *Probit Analysis*, pp 318. Cambridge University Press, Cambridge.
- Jayaraj S and Rabindra R J. 1989. Progress and perspectives in the use of biocontrol agent for integrated pest management of India.

- Proceedings of Seventh Session of Indian Science Congress* Madurai, 1980, p 23.
- Odak S C and Rawat R R. 1982. Integrated control of gram podborer, *Heliothis armigera* Hubner (Lepidoptera: Noctuidal). *Final Report, Adhoc ICAR Scheme (1978-82), Department of Entomology, Jawaharlal Nehru Krishi Vishwa vidyalay, Jabalpur, Madhya Pradesh*, pp 106.
- Rabindra R J. 1992. Genetic improvement of baculoviruses. (in) *Emerging Trends in Biological Control of Phytophagous Insects*. pp 183-6 T N Ananthakrishnan (Ed). Oxford and IBH Publ Co Pvt Ltd, New Delhi.
- Rabindra R J. 1999. Characterization of four geographic isolates of nuclear polyhedrosis virus of *Amsacta albistriga* by restriction endonuclease analysis (Abstract). Presented in National Symposium on Emerging Trends in Biotechnological Applications for Integrated Pest Management, held during 25-26 February 1999 at Loyola College, Chennai.
- Ramesh Arora, Battu G S and Bath D S. 1997. Comparative evaluation of some native isolates of a nuclear polyhedrosis virus against *Heliothis armigera* (Hubner). *Journal of Entomological Research* 21 (20) :183-6.
- Shapiro M and Robertson J L. 1992. Enhancement of baculovirus activity of the gypsy moth (Lepidoptera : Lymantriidae) by optical brighteners. *Journal of Economic Entomology* 85 : 1120-4.

Evaluation of resistance in blackgram (*Phaseolus mungo*) to variants of mungbean yellow mosaic geminivirus*

KAJAL KUMAR BISWAS¹ and ANUPAM VARMA²

Advanced Centre for Plant Virology, Division of Plant Pathology, Indian Agricultural Research Institute
New Delhi 110012

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Key words: blackgram, mungbean yellow mosaic virus, resistance and *Phaseolus mungo*

Yellow mosaic disease (YMD) caused by mungbean yellow mosaic geminivirus (MYMV) is a serious constraint in the cultivation of various leguminous crops in India (Varma *et al.* 1992). MYMV is transmitted by whitefly (*Bemisia tabaci* Genn.), but it is not seed-borne (Nariani 1960). The genome of MYMV consists of two single stranded circular DNA molecules designated as DNA-A and DNA-B. A majority of the cultivated varieties of blackgram are highly susceptible to MYMV resulting in loss of yield and impairment of quality. Variation in the incidence of yellow mosaic disease caused by MYMV has been observed between locations, time and cultivars of different host crops. Serological and nucleic acid hybridization tests have also indicated occurrence of natural variants of MYMV (Mandal and Varma, 1996; Biswas and Varma 2000). In this paper reaction of 15 cultivars of blackgram (*Phaseolus mungo* L.) to five natural variants of MYMV is described based on natural infection under field conditions and vector inoculation under glasshouse conditions, and confirmation of infection by nucleic acid spot hybridization (NASH).

Fifteen cultivars of blackgram were screened for resistance to MYMV variants Bg3, MbD, MoL, MbS and Pp1 (Biswas and Varma 2000). These variants were maintained on susceptible 'Pusa 2' blackgram through whitefly transmission in separate insect-proof glasshouses. Whitefly colonies were maintained on bottlegourd and tobacco by serial transfer. Adult whiteflies were given acquisition access period on virus source plants for 18 hr. Eight to ten viruliferous whiteflies/plant were released on healthy test plants at the two leaf stage and given inoculation access period of 24 hr; the test plants were covered with macro-cages described earlier (Mandal and Varma 1996). After inoculation access period, the whiteflies on test plants were killed by insecticide (0.05%

Decis 2.8 EC) and the plants were kept in insect-proof glasshouses for 30 days for symptom development. The severity of infection was recorded using the following 5 point scale: 0, immune/symptomless; 1, highly resistant (0.1 – 5.0% plant parts infected); 2, resistant (5.1 – 25 % plant parts infected); 3, susceptible (25.1 – 50% plant parts infected), and 4, highly susceptible (above 50% plant parts infected).

All the 15 cultivars of blackgram were also evaluated for resistance to yellow mosaic disease under field conditions at the experimental farm of the Institute in two successive *khari* seasons in 1994 and 1995 in completely randomized block design with three replications. The plant to plant distance was kept 8–10 cm, in 4 m rows. The row to row distance was 60 cm. Symptoms, severity and incidence of yellow mosaic disease were recorded up to 45 days after sowing. The symptomatic and symptomless plants were checked for MYMV infection by nucleic acid spot hybridization using probes to DNA-A and -B of MYMV-Bg3. For the preparation of probes the clones of DNA-A and -B of MYMV-Bg3 (Mandal and Varma 1996) were used and full length probes were prepared incorporating radiolabelled (32 P) d CTP by random priming method (Feinberg and Vogelstein 1984). Total DNA samples were isolated from young leaves three weeks after inoculation from glasshouse and six weeks after sowing in field conditions by the method described by Maule *et al.* (1983). For detecting MYMV in plants 2.5 µg (dilution 1), 0.25 µg (dilution 1/10) and 0.025 µg (dilution 1/100) nucleic acid were spotted on Hybond-N nylon membrane (Amersham). Hybridization method described by Mandal and Varma (1996) were used with suitable modification.

Resistance in blackgram cultivars to MYMV variants

Resistance in blackgram cultivars to MYMV varied from variant to variant. None of the fifteen cultivars tested was immune to MYMV variant Pp1 (Table 1) although, six cultivars were found to be highly resistant (scale 1) and four resistant (scale 2). Seven cultivars could not be infected by MYMV variant Bg3, as these cultivars neither developed

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¹Scientist (Plant Pathology), Indian Agricultural Research Institute, Regional Station, Kalimpong, West Bengal 734 301

²National Professor

Table 1 Reaction of different cultivars of blackgram to mungbean yellow mosaic virus variants

Cultivar	Infection of plants and symptoms developed by MYMV-Pp1			Disease severity* on infection with MYMV variants				
	Plant infected/plant inoculated		Symptom development (days)	Pp1	Bg3	MbD	MoL	MbS
	Exp I	Exp II						
'DPU 84-14'	10/20	4/11	11-20	1	0+	0+	0+	NT
'DPU 102'	4/19	NT	17	2	0+	1	0	NT
'KU 91'	17/17	NT	8	4	1	4	4	3
'LBG 629'	18/18	13/18	8-11	4	4	4	4	4
'Pant U 19'	5/14	NT	12	2	0	1	3	2
'PS 1'	2/19	3/12	13-18	1	0	0	NT	NT
'Pusa 2'	15/15	12/19	8-11	4	3	4	3	4
'T 9'	12/16	6/12	9-12	4	0	NT	2	1
'TAU 6'	4/17	6/12	12-18	2	0+	NT	0+	0+
'UG 218'	8/16	NT	10	2	0	1	0	NT
'UG 389'	7/15	NT	12	1	NT	NT	0+	NT
'UG 83-13'	6/17	3/9	12-20	1	2	1	0+	3
'UL 257'	2/16	3/17	17-24	1	0	1	0	0+
'UL 310'	2/18	4/18	17-24	1	0	0	NT	0
'UPG 89-6-7'	3/14	NT	13	3	0	NT	0+	0

*Disease severity on 0-4 scale; nT, Not tested, + Viral DNA detected by NASH. The symptomless cvs PS 1 against MbD, UG 218 and UL 310 against MoL, and UPG 89-6-7 against Bg3 and MbS were not tested by NASH

symptoms nor contained viral DNA, indicating immunity (scale 0). Three cultivars developed symptomless infection (latent infection) of MYMV Bg3, as the viral DNA was detected in these cultivars by NASH (Fig 1). Only one cultivar, LBG 629, was highly susceptible to Bg3 and also to all the other four variants of MYMV. Immunity to MbD, MoL and MbS was also recorded. Maximum symptomless infection occurred in tests with MoL, followed by with variants Bg3

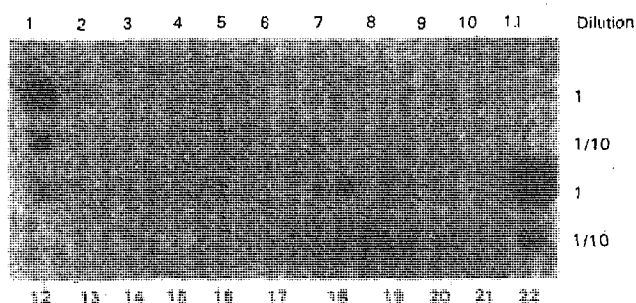


Fig 1 Detection of MYMV DNA of different variants in symptomless cultivars of blackgram by NASH with MYMV-Bg3 DNA-B probe. Lane 1: 'Pusa 2' infected with Pp1; Lane 2: 'DPU 84-14' with Bg3; Lane 3: 'DPU 84-14' with MbD; Lane 4: 'DPU 84-14' with MoL; Lane 5: 'DPU 102' with Bg3; Lane 6: 'DPU 102' with MoL; Lane 7: 'Pant U 19' with Bg3; Lane 8: 'PS 1' with Bg3; Lane 9: 'UG 83-13' with MoL; Lane 10: 'UG 218' with Bg3; Lane 11: 'T 9' with Bg3; Lane 12: 'UG 389' with MoL; Lane 13: 'UL 257' with MoL; Lane 14: 'UL 257' with MbS; Lane 15: 'UL 257' with Bg3; Lane 16: 'UL 310' with Bg3; Lane 17: 'UL 310' with MbS; Lane 18: 'UPG 89-6-7' with MoL; Lane 19: 'TAU 6' with Bg3; Lane 20: 'TAU 6' with MoL; Lane 21: 'TAU 6' with MbS; Lane 22: 'Pusa 2' infected with Pp1

and MbS (Table 1, Fig 1). MYMV variant Pp1 was most virulent as it infected all the blackgram cultivars tested. These results show that Pp1 is the most virulent variant of MYMV and TAU 6 most tolerant cultivar of blackgram to infection of MYMV. The reaction of selected cultivars to variant Pp1 was tested twice under the glasshouse condition. The severity of infection was consistent in both the experiments (Table 1). The resistant cultivars (scale 1 and 2) not only developed milder symptoms but also took longer time to appear (up to 12-24 days) as compared to symptoms in susceptible cultivars (up to 9-12 days).

Resistance to MYMV under field conditions

Under field conditions the symptom patterns differed from cultivar to cultivar. Overall incidence of MYMV was greater in 1994 than in 1995 season. In 1995, 'PS 1', 'UG 218' and 'UL 257' did not show any infection whereas in 1994 it ranged from 12 to 8.8% (Table 1). Overall reaction of different cultivars to MYMV under field and glasshouse conditions was similar. Of the various blackgram cultivars tested, 'DPU 84-14', 'DPU 102', 'UG 218', 'UG 389', 'UL 257' and 'UL 310' were found to be promising as they gave resistant to highly resistant reaction to MYMV under both the field and glasshouse conditions (Tables 1 and 2). In NASH tests the amount of viral DNA in highly resistant 'UL 257' was relatively less as would be expected in resistant cultivars. It was also found that the amount of DNA-A is less than DNA-B in infected plants (Fig 2).

The resistant or highly resistant cultivars of blackgram

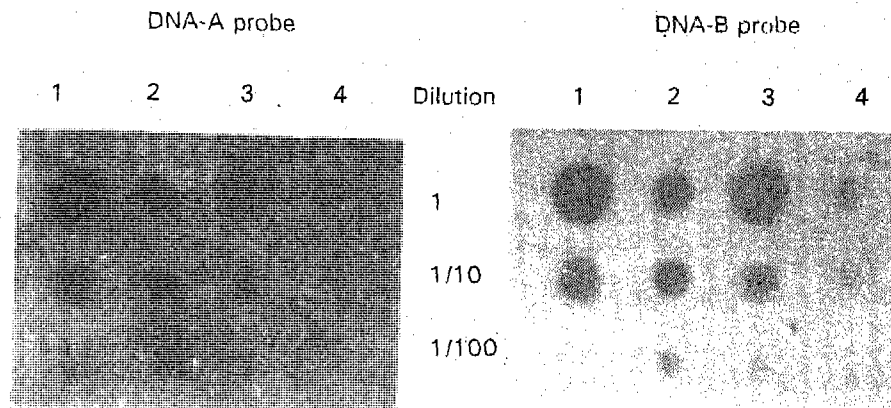


Fig 2 NASH showing relative concentration of MYMV DNA-A and -B under field conditions in different cultivars of blackgram. Lane 1: Highly susceptible 'Pusa 2'; Lane 2: Susceptible 'KU 91'; Lane 3 : Resistant 'UG 218'; Lane 4: Highly resistant 'UL 257'.

Table 2 Yellow mosaic incidence caused by mungbean yellow mosaic virus in different cultivars of blackgram under field conditions

Cultivar	Days to symptoms appearance after germination	Per cent infection	Maximum* severity		Maximum severity
			1994	Per cent infection	1995
'DPU 84-14'	20-28	8.9	2	3.9	2
'DPU 102'	24-37	1.3	2	2.4	2
'KU 91'	12-20	10.4	3	4.8	3
'LBG 629'	10-20	37.7	4	20.6	4
'Pant U 19'	17-37	2.9	2	7.2	2
'PS 1'	18-27	8.8	3	0.0	0
'Pusa 2'	12	26.7	4	23.5	4
'T 9'	20	4.9	4	5.5	3
'TAU 6'	10-20	4.0	2	9.4	3
'UG 218'	24-28	1.9	2	0.0	0
'UG 389'	30-37	2.8	2	1.2	1
'UG 83-13'	15-27	3.5	2	4.9	1
'UL 257'	10-20	1.2	1	0.0	0
'UL 310'	31-27	1.7	1	4.7	1
'UPG 89-6-7'	30-37	1.1	1	16.2	2
CD ($p=0.05$)		NS		9.6	
CD ($p=0.01$)		NS		12.9	

* Disease severity on 0-4 scale

identified under the field conditions matched the reactions obtained with MYMV-Pp1 under glasshouse condition, except that 'UPG 89-6-7' found susceptible to Pp1 in the glasshouse tests showed resistance under field conditions. This could be due to either field resistance in this cultivar or escape of infection by Pp1 under the natural conditions. Blackgram 'Pant U-19' was reported to be resistant to MYMV by Kausal and Singh (1988). In the present study also it showed field resistance, but it was susceptible to MoL. 'UG 218' and 'UL 257' were reported to be resistant to MYMV by earlier workers (Chhabra *et al.* 1993). These cultivars were also found resistant in the present investigation, except that the latter was infected symptomlessly by variant MbS. This is

the first time that symptomless infection of blackgram by MYMV has been reported. This finding has a bearing on breeding programmes for resistance to MYMV and on the development of yellow mosaic disease epidemic.

REFERENCES

- Biswas K K and Varma A. 2000. Identification of variants of mungbean yellow mosaic geminivirus by host reaction and nucleic acid spot hybridization. *Indian Phytopathology* 53 : 134-41.
- Chhabra K S, Kooner B S, Sharma A K and Saxena A K. 1993. Screening of blackgram genotypes against whitefly, jassids and yellow mosaic virus- role of phytochemicals in resistance. *Indian Journal of Pulse Research* 6 : 113-8.

- Feinberg A P and Vogelstein B. 1984. A technique for radio-labelling DNA restriction endonuclease fragments to high specific activity. *Analytical Biochemistry* **132** : 6-13.
- Kausal R P and Singh B M. 1988. Inheritance of resistance in blackgram (*Vigna mungo*) to mungbean yellow mosaic virus. *Indian Journal of Agricultural Science* **58** : 132-4.
- Mandal B and Varma A. 1996. Differentiation of natural variants of mungbean yellow mosaic geminivirus by host reactions and DNA-DNA hybridization. *International Journal of Tropical Plant Disease* **14** : 189-202.
- Maule A J, Hull R and Donson J. 1983. The application of spot hybridization to the detection of DNA and RNA viruses in plant tissue. *Journal of Virological Methods* **6** : 619-24.
- Mishra R C, Tripathi D and Saha R C. 1982. Yellow mosaic resistant mungbean for summer cultivation. *Indian Journal of Genetics and Plant Breeding* **38** : 103-5.
- Nariani T K. 1960. Yellow mosaic of mung (*Phaseolus aureus* L.). *Indian Phytopathology* **13** : 24-9.
- Varma A, Dhar A K and Mandal B. 1992. MYMV transmission and control in India. (in) *Mungbean Yellow Mosaic Disease*, pp 8-20, S K Green and Kim D (Ed). Asian Vegetable Research Development Centre, Taipei.

Evaluation of bell pepper (*Capsicum annuum*) germplasm for resistance against leaf blight and fruit rot (*Phytophthora nicotianae* var *nicotianae*)*

S VERMA¹, K R SHYAM², S K GUPTA³ and H R SHARMA⁴

Dr Y S Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh 173 230

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Key words: Germplasm, resistance, bell pepper, *Capsicum annuum* and *Phytophthora nicotianae* var. *nicotianae*

Leaf blight and fruit rot caused by *Phytophthora nicotianae* var. *nicotianae* is the most important disease of bell pepper (*Capsicum annuum* L.) causing huge losses to growers in India during the rainy season. This disease was first reported in 1971 from Solan, Himachal Pradesh to be caused by *Phytophthora capsici* Leon but later *P. nicotianae* var *nicotianae* was observed to be of common prevalence (Verma 1997). The fruit rot incidence and leaf blight severity have been reported to vary in between 30.4 and 68.7; and 35.0 to 62.7%, respectively. The pathogen is soil-borne in nature and infection of the plants takes place through rain-splashed zoospores. Though the disease can be kept under check with elaborate chemical sprays (Bhardwaj *et al.* 1985), the cost involved is very high besides the environmental pollution hazard, thus the use of resistant varieties is the only feasible means of controlling the disease.

Keeping this in view, 29 cultivars/germplasm lines of bell pepper were screened against leaf blight and fruit rot under natural epiphytotic conditions besides an interaction of the cultivars/lines and pathogen in relation to incubation period and lesion development under laboratory conditions were also recorded and are presented here in this communication.

The seedlings of each bell pepper cultivar/line were raised in trays filled with sterilized soil and 50 days old seedlings were transplanted in 4 m long rows, maintaining row-to-row and plant-to-plant distance of 60 and 45 cm, respectively. Ten seedlings were transplanted in each row in the first week of May 1997 and replicated three times and a single row of highly susceptible variety 'California Wonder' was planted around the rows in which test cultivars and lines were transplanted. The incidence and severity of fruit rot and leaf blight, respectively, were recorded at regular intervals. Fruit rot incidence was calculated by counting the total number of fruits and diseased fruits. The reaction of leaf blight was recorded on 0-4 scale (Verma 1997) and the per cent disease

severity was calculated by the following formula:

$$\text{Disease severity (\%)} = \frac{\text{Sum of all disease ratings}}{\text{Total number} \times \text{maximum disease of ratings grade}} \times 100$$

The different cultivars/lines were graded as resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible, depending upon 0-5, 5.1-10.0, 10.1-25.0, 25.1-50.0 and >50 % disease severity/incidence, respectively.

The apparent infection rate (r) and area under disease progress curve (AUDPC) for 7 cultivars/lines were also calculated by the following formula:

$$\ln [x_t / (1 - x_t)] = \ln [x_1 / (1 - x_1)] + r(t_2 - t_1)$$

$$\text{AUDPC} = \sum_{i=1}^n [(y_{i+1} + y_i) / 2] (t_{i+1} - t_i)$$

where, r is apparent infection rate and x_1 and x_2 are disease severity/incidence at time t_1 and t_2 , respectively, while y_1 and y_{i+1} are disease severity/incidence at time t_1 and t_{i+1} , respectively and n is the total number of observations.

Fruits were further evaluated under laboratory conditions against the disease. Immature healthy green fruits were surface sterilized with 70 % ethanol and then thoroughly washed with sterilized distilled water and dried on blotting paper. The fruits were inoculated by placing a drop (5 μ l) of sporangial suspension (9×10^4 sporangia/ml) on fruit surface. The inoculated fruits were incubated at $25 \pm 1^\circ\text{C}$ and more than 90 % relative humidity was maintained inside the bell jar by periodical water application or spray. The observations regarding incubation period and rate of lesion development (rd (mm/hr)) for each were calculated as :

$$r_d (\text{mm/hr}) = \frac{1d_2 - 1d_1}{t_2 - t_1}$$

where, rd is rate of lesion development (mm/hr); $1d_1$ and $1d_2$ are mean diameter at time t_1 and t_2 , respectively.

*Short note

¹Ph D Student, ²Professor, ³Scientist, Department of Mycology and Plant Pathology,

⁴Assistant Scientist, Horticultural Research Station, Kandaghat 173 215

Table 1 Reaction of bell pepper cultivars/lines to *Phytophthora nicotianae* var *nicotianae* under natural epiphytotic conditions and host-pathogen interaction

Cultivars/lines	Leaf blight severity (%)	Scale	Fruit rot incidence (%)	scale	Reaction	Incubation period (hr)	Mean rate of lesion development (mm/hr)	Range of rate of lesion development (mm/hr)
Kandaghat Selection	0	0-5	0	0	R	-	0.0	
EC 382679	5.1	5.1-10.0	3.14	0.1-10.0	MR	188	0.15	0.042-0.24
EC 393212	5.1		3.15		MR	186	0.14	0.063-0.27
HC 202	5.2		3.16		MR	264	0.28	0.04-0.52
EC 392688	5.3		3.16		MR	240	0.33	0.14-0.52
EC 393213	8.25		4.16		MR	138	0.16	0.02-0.35
EC 393214-2	10.00		8.33		MR	185	0.33	0.19-0.50
EC 392684	10.58	10.1-25.0	12.34	10.1-25.0	MS	160	0.34	0.2-0.51
Early Prolific	11.06		13.44		MS	144	0.32	0.13-0.73
EC 393215	14.18		16.57		MS	142	0.30	0.19-0.41
EC 392678	16.68		18.67		MS	75	0.25	0.043-0.44
EC 392686	18.70		21.75		MS	114	0.43	0.13-0.78
Feroz	24.42		25.00		MS	89	0.44	0.21-1.78
EC 392682	26.25	25.1-50.0	27.06	25.1-50.0	S	73	0.39	0.31-0.50
EC 203583	28.75		29.38		S	114	0.79	0.55-1.07
HrB	30.00		30.00		S	48	0.34	0.14-0.50
Bhowali	36.25		35.92		S	72	0.69	0.28-1.00
Yolo Wonder	37.50		38.00		S	88	0.88	0.25-1.80
EC 393214-1	38.75		40.00		S	67	0.73	0.21-2.06
EC 392681	50.44	>50	45.44	>50	HS	27	0.33	0.013-1.63
California Wonder	53.50		47.50		HS	24	0.42	0.09-0.90
Novosibirski	54.00		48.85		HS	27	0.52	0.14-1.06
EC 119051	55.14		50.14		HS	27	0.56	0.38-0.88
COO 505	56.35		50.37		HS	27	0.59	0.19-0.82
Osh Region	56.45		51.47		HS	17	0.38	0.25-0.52
EC 392685	57.10		53.41		HS	17	0.46	0.23-0.86
HC 201	58.50		54.85		HS	27	0.79	0.19-1.15
EC 392680	60.20		56.22		HS	27	0.84	0.38-1.14
EC 392687	60.50		56.25		HS	16	0.50	0.13-1.09

R, Resistant; MR, moderately resistant, MS, moderately susceptible, S, susceptible, HS, highly Susceptible

Kandaghat Selection was found resistant which remained completely free of leaf blight and fruit rot, whereas six lines, viz EC 392679, EC 393212, HC 202, EC 392688, EC 393213 and EC 393214-2 exhibited from 5.1 to 10.0% leaf blight severity and fruit rot incidence varied from 3.14 to 8.33% while the remaining cultivars/lines exhibited moderately susceptible to highly susceptible reaction (Table 1).

Cultivars/lines - pathogen interaction in relation to incubation period and lesion development indicated that the incubation period in different cultivars/lines varied from 16 to 264 hr with mean rate of lesion development ranging from 0.14 to 0.88 mm/hr. Longest incubation period of 264 hr was observed in HC 202 followed by EC 392688, EC 382679, EC 393212, EC 393214-2 and EC 392684 with incubation periods of 240, 188, 185 and 160 hr respectively. Interestingly, Kandaghat Selection, which stayed disease free under natural epiphytotic, also remained disease free under *in vitro* studies.

The rate of lesion development was observed to be lowest on the fruits of EC 393212, closely followed by EC 382679, EC 393213, EC 392678, HC 202, EC 393215, Early Prolific, EC 392681, EC 392688, EC 393214-2 and EC 392684. The cultivars/lines, which were rated as moderately resistant and moderately susceptible, generally had longer incubation periods and lower rates of lesion development.

Levels of resistance and susceptibility of different cultivars/lines revealed that irrespective of the spread of the disease on leaves and fruits, apparent infection rate and area under disease progress curve (AUDPC) increased with the progressive decrease of resistance fading into a category of highly susceptible disease reaction (Table 2). The moderately resistant lines EC 393213 and EC 393214-2 exhibited minimum infection rate 0.11 and 0.116/ unit/ day, respectively, for the spread of leaf blight and 0.076 and 0.1/ unit/day for fruit rot while the corresponding values of

Table 2 Level of resistance/ susceptibility of some cultivars/ lines in relation to apparent infection rate and AUDPC

Cultivars/ lines	Reaction	Apparent infection rate (r)/ unit/ day		AUDPC	
		Leaf blight	Fruit rot	Leaf blight	Fruit rot
'EC 393213'	MR	0.110 ^a	0.076 ^a	0.73 ^a	0.36 ^a
'EC 393214-2'	MR	0.116 ^a	0.100 ^b	0.89 ^b	0.74 ^b
'EC 392678'	MS	0.126 ^b	0.128 ^c	1.95 ^c	1.66 ^c
'EC 392686'	MS	0.131 ^b	0.131 ^c	2.67 ^d	2.57 ^d
'EC 203583'	S	0.134 ^{bc}	0.132 ^c	2.95 ^c	2.62 ^c
'Bhowali'	S	0.143 ^c	0.142 ^d	3.24 ^f	3.21 ^f
'California Wonder'	HS	0.158 ^d	0.150 ^e	4.78 ^e	4.25 ^e
'Novosibirski'	HS	0.159 ^d	0.152 ^e	4.84 ^b	4.79 ^b
CD (P= 0.05)		0.007	0.007	0.014	0.021

AUDPC were 0.73 and 0.89 for leaf blight and 0.36 and 0.74 for fruit rot. Highest 'r' (0.158 and 0.159/unit/day), values were observed in case of highly susceptible varieties 'California Wonder' and 'Novosibirski', respectively, while corresponding values of AUDPC were 4.78 and 4.84 for leaf blight and 4.25 and 4.79 for fruit rot. It is also evident from the Table 2 that the lines exhibiting moderately resistant reaction exhibited significantly lower values of apparent infection rates and AUDPC compared to the cultivars/ lines ranging in their reactions from moderately susceptible to highly susceptible.

Among the 29 cultivars/ lines screened for resistance against the pathogen, only Kandaghat Selection was found resistant both under natural epiphytotic conditions as well as under laboratory conditions which remained disease free while the six lines EC 392679, EC 393212, HC 202, EC 392688, EC 393213 and EC 393214-2 were observed as moderately resistant and the remaining were recorded as moderately susceptible to highly susceptible. Results of the *in vitro* studies of cultivars/ lines - pathogen interaction in relation to incubation period and lesion development generally reflected that the cultivars/lines which were rated as moderately resistant and moderately susceptible under *in vivo* conditions were found to have longer incubation periods and lower rates of lesion development. Therefore, it can be concluded that higher degree of horizontal resistance is present in the moderately resistant cultivars/lines as reflected by the components of horizontal resistance, ie longer incubation periods and lower rates of lesion development.

The results of the studies on relationship between levels of resistance/ susceptibility of the cultivars/ lines, apparent infection rate (r) and area under disease progress curve (AUDPC) for the development of the disease further indicated that the apparent infection rate and area under disease progress curve were inversely proportional to the degree of resistance. GilOrotga *et al.* (1987) described that the resistant lines had lower infection rate than the susceptible lines, and reported INIA 224 as susceptible line and PI 201232 as resistant line.

The foregoing discussion clearly indicates that only 'Kandaghat Selection' was found resistant both under field as well as laboratory conditions. Higher degree of horizontal resistance was present in the moderately resistant cultivars/ lines as reflected by longer incubation periods and lower rates of lesion development. The development of the disease further indicated that the apparent infection rate (r) and AUDPC were inversely proportional to the degree of resistance.

REFERENCES

- Bhardwaj S S, Sharma S L and Dohroo N P. 1985. Role of meteorological factors in development of bell pepper fruit rot (*Phytophthora nicotianae* var *nicotianae* Waterhouse). *Indian Journal of Mycology and Plant Pathology* 15: 328-9.
- GilOrotga R, Palazon Espanol C and J Cuartero Zueco. 1987. Response of pepper to inoculation with *Phytophthora capsici* at different day lengths and temperatures. *Capsicum Newsletter* 6 : 68-9.
- Verma S. 1997. 'Epidemiology and management of leaf blight and fruit rot of bell pepper'. M Sc thesis, UHF, Solan.

Probability of monsoon rainfall and crop planning for Kalahandi (Orissa)*

DILIP KUMAR BASTIA¹ and SUSANT KUMAR MOHANTY²

Regional Research Station, Orissa University of Agriculture and Technology, Bhubaneswar 766 001

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The Kalahandi district of Orissa is perpetually drought-hit. Although the normal rainfall of the district is 1352mm yet the area encounters intermittent and terminal drought almost every year. It is an established fact that if the dry spells coincide with sensitive phenological stages of crops, this will cause damage to the crop development. Hence for the purpose of crop planning and to carry out agricultural practices, it is important to know the sequence of dry and wet periods (Pandarinath 1991). To find out the long-term frequency behaviour of wet or dry weather spells Markov chain probability concept has been extensively used (Victor and Sastry 1979). When applied to periods like week, this concept enables to determine the probability of occurrence of dry or wet weather during the succeeding week (Pandarinath 1991). A number of agrometeorological researchers have demonstrated its practical utility in agricultural planning (Dash and Senapati 1992, Pandarinath 1991, Victor *et al.* 1991). Farmers' cropping strategies are greatly influenced by the onset of monsoon and its weekly variability (Victor *et al.* 1991). Hence correlating all these factors of varying probabilities, a feasible crop planning for Kalahandi district has been formulated.

Rainfall data of 25 years (1974-98) have been collected on daily basis for computation. It is observed that the distribution of rainfall in Kalahandi is quite uneven and erratic. About 85% of annual rainfall occurs during the south-west monsoon from third week of June to last week of September in around 59 rainy days. Probability of weekly rainfall was analysed basing on the Markov chain as described by Pandarinath (1991). In the present analysis 25 mm rainfall/week has been considered as a dry week and 26 mm and above rainfall as a wet week. The different notations followed in this method of computation are: (i) $P(d) = F(d)/N$, where $P(d)$ is probability of the week being dry, N is number of years of data used; $F(d)$ is frequency of dry weeks. (ii) $P(dd) = F(dd)/F(d)$, where $P(dd)$ is probability of dry week preceded by another dry week (conditional), $F(dd)$ is frequency of dry week preceded by another dry week and $F(d)$ is the frequency

of preceded dry week. (iii) $2D = P(d)_{\text{week1}} \times P(dd)_{\text{week2}}$, where $2D$ is probability of second consecutive dry weeks, given that preceding week is dry. (iv) $3D = P(d)_{\text{week1}} \times P(dd)_{\text{week2}} \times P(dd)_{\text{week3}}$, where $3D$ is probability of three consecutive dry weeks, $P(dd)_{\text{week3}}$ is probability of third week being dry, given that preceding weeks are dry. (v) $P(w) = F(w)/N$, where $P(w)$ is probability of the week being wet, N is number of years of data used; $F(w)$ is frequency of wet weeks. (vi) $P(ww) = F(ww)/F(w)$, where $P(ww)$ is probability of wet week preceded by another wet week (conditional), $F(ww)$ is frequency of wet week preceded by another wet week and $F(w)$ is the frequency of preceded wet week. (vii) $2W = P(w)_{\text{week1}} \times P(ww)_{\text{week2}}$, where $2W$ is probability of second consecutive wet weeks, given that preceding week is wet. (viii) $3W = P(w)_{\text{week1}} \times P(ww)_{\text{week2}} \times P(ww)_{\text{week3}}$, where $3W$ is probability of three consecutive wet weeks, $P(ww)_{\text{week3}}$ is probability of third week being wet, given that preceding weeks are wet.

Weekly rainfall associated with period of onset of monsoon and its variability have been computed using simple statistical formula.

Probability of dry and wet spell

It is evident from the result (Table 1) that the probability of occurrence of a dry week is high (68%) up to 23 week of the year and it falls in subsequent weeks and remains below 50% up to 38 week. Similarly the probability of occurrence of wet week is low up to 23 week (32%) and thereafter it remains above 50% up to 38 week. The conditional probability of dry week preceded by a dry week maintains the same trend as the probability of occurrence of a dry week, where as the conditional probability of wet week preceded by a wet week remains above 50% from 23 week up to 38 week. The probability of occurrence of two and three consecutive dry weeks are below 50% from 23 to 38 week and from 22 to 39 week respectively. On the other hand, the probability of occurrence of two and three consecutive wet weeks are above 50% from 25 to 37 week and 25 to 35 week respectively.

Onset and withdrawal of monsoon

The mean weekly rainfall associated with different period

*Short note

¹Technical Officer (Agromet Advisory Service), ²Post Graduate Research Fellow

Table 1 Initial and conditional probability of dry and wet spells

Standard meteorological Week	F(d)	F(dd)	P(d) %	P(dd) %	2D %	3D %	F(w)	F(ww)	P(w) %	P(ww) %	2W %	3W %
22	14	14	56	61	52	24	11	00	44	00	28	25
23	17	13	68	93	32	04	08	07	32	64	28	18
24	09	08	36	47	04	01	16	07	64	88	40	40
25	07	01	28	11	08	03	18	10	72	63	72	55
26	03	02	12	29	04	01	22	18	88	100	68	60
27	06	01	24	33	08	00	19	17	76	77	68	68
28	05	02	24	33	00	00	20	17	80	89	80	57
29	01	00	04	00	40	00	24	20	96	100	68	64
30	08	01	32	100	00	00	17	17	68	71	64	48
31	01	00	04	00	00	00	24	16	96	94	72	68
32	06	00	24	00	04	01	19	18	76	75	72	66
33	03	01	12	17	04	00	22	18	88	95	80	62
34	03	01	12	33	00	00	22	20	88	91	68	47
35	05	00	20	00	08	04	20	17	80	77	56	56
36	09	02	36	40	16	05	16	14	64	70	64	38
37	03	04	12	44	04	03	22	17	88	100	52	14
38	10	01	40	33	28	21	15	13	60	59	16	02
39	17	07	68	70	52	43	08	04	32	27	04	0.5
40	18	13	72	76	60	54	07	01	28	13	03	0.4
41	20	15	80	83	72	70	05	01	20	14	02	00

F(d), frequency of dry weeks; F(dd), frequency of dry week preceded by another dry week; P(d), first dry week; P(dd), second consecutive dry weeks; 2D, probability of second dry week; 3D, probability of third dry week; F(w), frequency of wet weeks; F(ww), frequency of wet week preceded by another wet week; P(w), first wet week; P(ww), second consecutive wet weeks; 2W, probability of second wet week; 3W, probability of third wet week

Table 2 Mean weekly rainfall associated with different period of onset of south-west monsoon

Standard meteorological week	Period of onset of south-west monsoon						
	28 May 10 June	CV (%)	11-24 June	CV (%)	25 June 8 July	CV (%)	9-22 July
22	48.40	37.25					
23	59.80	74.23					
24	64.41	44.41	82.56	110.26			
25	107.97	111.68	83.72	70.37			
26	90.34	120.18	88.58	64.24	84.76	29.03	
27	59.36	50.62	49.84	74.86	121.38	83.76	
28	72.82	93.42	92.16	84.17	61.75	45.49	27.0
29	87.92	30.29	134.64	86.36	141.24	44.30	78.0
30	163.18	64.52	64.78	78.13	87.66	63.97	24.0
31	63.84	64.97	98.15	50.16	158.63	69.22	159.2
32	22.80	99.96	148.27	58.27	66.26	89.63	15.2
33	116.64	69.67	143.42	97.86	26.90	88.10	98.6
34	83.88	62.76	92.46	62.82	82.26	71.75	165.0
35	64.40	57.50	101.14	55.48	44.80	71.05	63.2
36	131.10	64.52	50.36	99.82	50.89	76.26	71.4
37	72.04	51.57	94.46	78.76	155.33	131.24	33.4
38	60.96	157.50	40.18	90.42	17.20	105.81	91.6
39	14.14	87.77	24.86	142.82	23.93	100.42	19.0
40	114.40	179.76	20.47	126.36	7.15	90.21	00.0
41	32.60	73.01	5.96	174.27	5.25	173.1	00.0
Frequency of onset of monsoon	5 years		15 years		4 years		1 year

of onset of south-west monsoon has been presented in Table 2. It is observed that out of the 25 years under study, monsoon has started within 28 May to 10 June in 5 years, 11 June to 24 June in 15 years, 25 June to 8 July in 4 years and beyond 8 July in one year. The result further reveals that when monsoon starts within 28 May to 10 June, there is every probability that there will be erratic rainfall in 25 and 26 week and a dry spell on 32 week. Similarly when monsoon starts between 11 June to 24 June an assured rainfall can be expected from 25 to 37 week barring some contingencies on 33 and 36 week. When rainfall starts within 25 June to 8 July, it is expected that there will be assured rainfall from 26 week to 36 week. Rainfall starting beyond 8 July is exceptional, hazardous and never reliable.

Crop planning

It is observed from onset of monsoon that when monsoon starts early before 2 week of June, seeding operation can only be taken up after enough soil moisture regime has built up to sustain the seedlings in contingencies expected to be encountered in the 25 and 26 week. The crops may also come across a dry spell in the 32 week. In such condition, short duration and low-duty crops like blackgram, maize, groundnut and sunflower can be taken early, instead of traditional paddy crop, to accommodate a second crop in cropping sequence as the area is likely to get around 16 weeks of rainfall. On the other hand, when monsoon breaks normally around 3-week of June, any crop can be taken up as per the socio-economic requirement. But as high duty crop like paddy (*Oryza sativa* L.) is generally grown extensively, contingent arrangement is required to irrigate the crop in 33

week and 36 week onwards, which coincide with critical phenophases of the crop. However for the progressive farmers, crop substitution like hybrid cotton, soybean, sunflower and vegetables have been found to fetch higher return with insurance against intermittent drought. On the contrary, monsoon breaking beyond 3 or 4 week of June leaves only 8-10 weeks of cropping season. There is also high degree of risk for intermittent and terminal drought. In such type of situation only the crops like legumes and minor millets have been found to be successful. Intercropping of extra-early paddy with arhar has also proved to reduce risk factor besides fetching incremental return.

Regarding conditional probability of dry weeks, caution should be observed when the 29 week becomes a dry week. In this case, field bunds may be tightened and water be preserved for life-saving irrigation to different crops in subsequent expected dry weeks.

REFERENCES

- Dash M K and Senapati P C. 1992. Forecasting of dry and wet spells at Bhubaneswar for agricultural planning. *Indian Journal of Soil Conservation* 20 (1&2): 75-82
- Pandarinath N. 1991. Markov Chain model probability of dry and wet weeks during monsoon period over Andhra Pradesh. *Mausam* 42 (4) : 393-400.
- Victor U S and Sastry P S N. 1979. Dry spell probability by Markov Chain model and its application to crop development stage. *Mausam* 30 : 479-84.
- Victor U S, Ramana Rao B V, Srivastava N N and Vijayakumar P. 1991. Rainy season and its variability for contingency crop planning in Andhra Pradesh. *Indian Journal of Dryland Agricultural Research and Development* 6 (1&2):1-2.

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