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Effect of Plant Population Densities on the Severity of Late Leaf Spot and Rust of Groundnut

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The effect of five plant population densities [5 (D_1), 10 (D_2), 20 (D_3), 30 (D_4), and 40 (D_5) plants/m^2] of four groundnut cultivars [ICGV 86699, ICG (FDRS) 10, ICGS 11 and TMV 2] and fungicide application (Kavach, chlorothalonil) to manage late leaf spot (LLS) and rust were studied in a field experiment during the 1995 and 1996 rainy seasons. LLS and rust severities were low in fungicide sprayed plots in all the cultivars irrespective of plant densities. Severities of LLS and rust, and percentage defoliation caused by LLS were significantly more in higher plant densities (D_4, D_5) than in lower plant densities (D_1, D_2, D_3) in fungicide sprayed and unsprayed plots in all the cultivars. All the cultivars gave significantly higher haulm and pod yields in fungicide sprayed plots than in unsprayed plots. Haulm and pod yields were significantly higher in higher plant densities than in lower plant densities. A combination of higher plant densities (D_4, D_5) and fungicide protection against LLS and rust gave maximum yield.

Keywords : *Arachis*, peanut, *Phaeoisariopsis personata*, *Puccinia arachidis*.

Groundnut (*Arachis hypogaea* L.) is an important legume crop in many tropical and subtropical countries of the world. It is prone to attack by many fungal foliar and soil-borne diseases. The most important fungal foliar diseases of groundnut worldwide are late leaf spot (LLS) caused by *Phaeoisariopsis personata* [(Berk. and Curt.) v. Arx] = *Cercosporidium personatum* [(Berk. & Curt.) Deighton] and rust caused by *Puccinia arachidis* Speg. These two diseases together can cause yield loss of more than 50%, if the crop is not protected with chemicals (Smith and Littrell, 1980; Gorbet et al., 1982; Johnson and Beute, 1986). In developed countries like the USA, the use of fungicide application after every 10-14 days, beginning at 30-35 days after sowing (DAS) and continuing throughout the crop season to control LLS and rust is being practiced to achieve higher yields (Shokes et al., 1982). However, in most developing countries, groundnut is grown mainly by resource-poor farmers who can hardly afford chemical protection. Hence, yield losses often reach more than 50% (Gibbons, 1980).

The best way to control these foliar diseases is to grow resistant cultivars, but high levels of resistance are not available in high yielding groundnut cultivars. Therefore, modified agronomic practices like plant population densities, date of planting, crop rotation, sanitation, and/or economical use of fungicides can be used to manage these diseases (Yayock, 1981). Plant densities have profound influence on the development of foliar diseases in many crops. Higher plant densities support foliar diseases like botrytis gray mold of chickpea (Pande et al., 1998). The objective of this study was to find out the optimum plant density to manage LLS and rust diseases and to achieve maximum yields in groundnuts.

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Materials and Methods

This study was conducted in an Alfisol field during the 1995 and 1996 rainy seasons at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, near Hyderabad, India. Sowings were done in the last week of June in both years. Four groundnut cultivars (ICGV 86699, ICG (FDRS) 10, ICGS 11, and TMV 2) with varying levels of resistance to LLS and rust were included in this trial. The characteristics of the cultivars used in this experiment are given in Table 1. The experiment was carried out in a split-split plot design with fungicide spray as the main plots, cultivars as the sub-plots, and plant densities as the sub-sub-plots with four replications. The crop was raised on flat beds in 4×4 m plots. Each cultivar had five plant densities of 5 (D_1), 10 (D_2), 20 (D_3), 30 (D_4), and 40 (D_5) plants/m^2. To maintain these densities, the inter- and intra-row spacing followed were: 50×40 cm, 50×20 cm, 50×10 cm, 33×10 cm, and 25×10 cm for D_1, D_2, D_3, D_4, and D_5 respectively. Fungicide (Kavach, chlorothalonil) at 2 g/l water and 800 liters of chemical solution/ha was used at 15-day interval from 30 days after sowing (DAS) until maturity of the crop to control LLS and rust. Total rainfall (mm) and number of rainy days during the crop season for both years were recorded and given in Table 2.

Five random plants were selected and tagged at 30 DAS for disease assessment in each plot. Percentage leaf area damaged by

Table 1. Characteristics of groundnut cultivars used in the experiments

Cultivar	Botanical type	Seed color	Days to Maturity	Origin	Reaction to	
					LLS[a]	Rust[b]
ICGV 86699	Verginia	Red	130	ICRISAT, India	R[c]	R
ICG (FDRS)10	Valencia	Tan	115	ICRISAT, India	MR[d]	R
ICGS 11	Spanish	Tan	120	ICRISAT, India	MR	S[e]
TMV 2	Spanish	Tan	110	India	HS[f]	HS

[a] Screened for late leaf spot (LLS) under artificial epidemic conditions in field and scored on 1-9 disease rating scale where, 1=No disease, all leaves healthy; 2=Lesions present largely on lower leaves, no defoliation; 3=Lesions present largely on lower leaves, very few on middle leaves, defoliation on some leaflets evident on lower leaves; 4=Lesions on lower and middle leaves but severe on lower leaves; 5=Lesions present on all lower and middle leaves, over 50% defoliation of lower leaves; 6=Severe lesions on lower and middle leaves, lesions present but less severe on top leaves, extensive defoliation of lower leaves, defoliation of some leaflets evident on middle leaves; 7=Lesion on all leaves but less severe on top leaves, defoliation of all lower and some middle leaves evident; 8=Defoliation of all lower and middle leaves, severe lesions on top leaves, some defoliation of top leaves evident; and 9=Almost all leaves defoliated leaving bare stems, some leaflets may remain, but show severe leaf spots.

[b] Screened for rust under artificial epidemic conditions in field and scored on 1-9 disease rating scale where, 1=No disease, all leaves healthy; 2=Few, very small pustules on some older leaves; 3=Few pustules, mainly on older leaves, some ruptured, poor sporulation; 4=Pustules small or large, mostly on lower and middle leaves, disease evident; 5=Many pustules, mostly on lower and middle leaves, yellowing and necrosis of some lower and middle leaves, moderately sporulating; 6=As rating 5 but pustules heavily sporulating; 7=Pustules all over the plant, lower and middle leaves withering; 8=As rating 7 but withering is severe and 9=Plants severely affected, 50-100% leaves withering.

[c] Resistant (<3 on 1-9 rating scale).

[d] Moderately resistant (4 and 5 on 1-9 rating scale).

[e] Susceptible (6 and 7 on 1-9 rating scale).

[f] Highly susceptible (8 and 9 on 1-9 rating scale).

Table 2. Rainfall and number of rainy days during the groundnut crop season in 1995 and 1996

Month	1995		1996	
	Rain (mm)	No. of rainy days	Rain (mm)	No of rainy days
July	252.0	18	211.3	17
August	245.6	15	450.8	22
September	112.9	11	160.8	14
October	361.0	14	83.6	8
November	13.0	1	22.4	1
Total	984.5	59	928.9	62

LLS and rust, and percentage defoliation caused by LLS were recorded from 45 DAS to 105 DAS at 15-day interval in all the treatments. All the leaves on the main stem of each plant were assessed for leaf area damage by LLS and rust by comparing each leaf with the diagrams depicting leaves with known percentages of their areas affected (Hassan and Beute, 1977). The number of defoliated leaflets was counted at each assessment, and percentage of defoliation caused by LLS was calculated based on total and defoliated leaflets. At maturity, the cultivars were harvested from 3×3 m net area in each plot, leaving a 1×1 m border all around to eliminate border effect on yield components. The harvested crop was dried in windrows for 3 days. Pods were then hand picked and sun dried for another 3-4 days until ≤10% moisture content was attained. Haulm and pod weights were taken from each plot and yield ha^{-1} was calculated.

Data analysis. Severities of LLS and rust, defoliation caused by LLS, haulm, and pod yields were similar in 1995 and 1996 seasons and were found insignificant between years. Hence, the data for both years was analyzed using analysis of variance (ANOVA). Least significant difference (LSD) at 5% level of significance was used to assess significance of difference of means among treatments.

Results

Effects on late leaf spot (LLS). Significant differences in percentage leaf area damage by LLS ($P<0.05$) were observed between fungicide sprayed and unsprayed treatments. All the four cultivars had less leaf area damage caused by LLS in fungicide sprayed plots than in unsprayed plots in all plant densities. The resistant cultivar ICGV 86699 had the lowest disease severity among all plant densities in both fungicide sprayed and unsprayed plots than that of the other cultivars. The susceptible cultivar TMV 2 had significantly more leaf area damaged by LLS in all plant densities than the other cultivars irrespective of fungicide treatments. The moderately resistant cultivars ICG (FDRS) 10 and ICGS 11 had significantly low disease occurrence in all the plant densities in fungicide sprayed treatment than in unsprayed treatment. These two cultivars had comparatively more leaf area damaged by LLS in higher plant densities (D_4, D_5) than in lower plant densities in unsprayed plots (Fig. 1). Severity of LLS in ICGV 86699 remained low (-2%) in all plant densities throughout the crop season in both fungicide sprayed and unsprayed plots. All the plant densities of moderately resistant ICG (FDRS) 10 and ICGS 11 had low disease severity (<3%) until maturity in fungicide sprayed plots, whereas, the severity

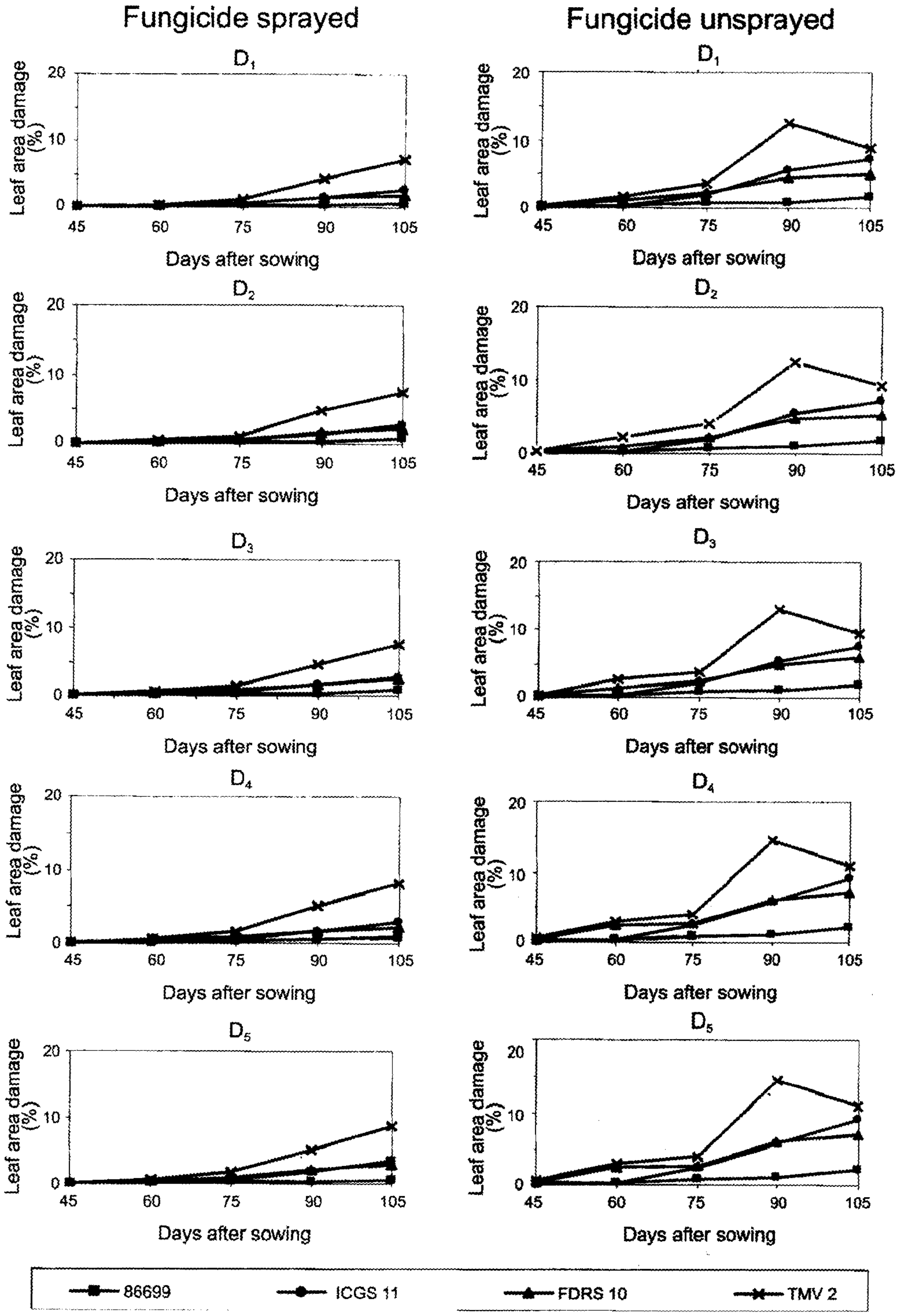

Fig. 1. Late leaf spot disease progress of four groundnut cultivars in different plant densities in fungicide, Kavach sprayed and unsprayed treatments. D_1=5 plants/m^2; D_2=10 plants/m^2; D_3=20 plants/m^2; D_4=30 plants/m^2; D_5=40 plants/m^2.

remained low (<3%) up to 75 DAS in unsprayed plots. In these two cultivars, the disease progressed slowly after 75 DAS and recorded up to 9% of the leaf area damaged at maturity. The susceptible TMV 2 had low disease rate (<4%) up to 75 DAS. Thereafter, the disease progressed and reached maximum (-10.8%) in all plant densities in both fungicide sprayed and unsprayed treatments (Fig. 1).

Effects on rust. Significant differences (P<0.05) in percentage leaf area damage by rust were found between fungicide sprayed and unsprayed treatments. Severity of

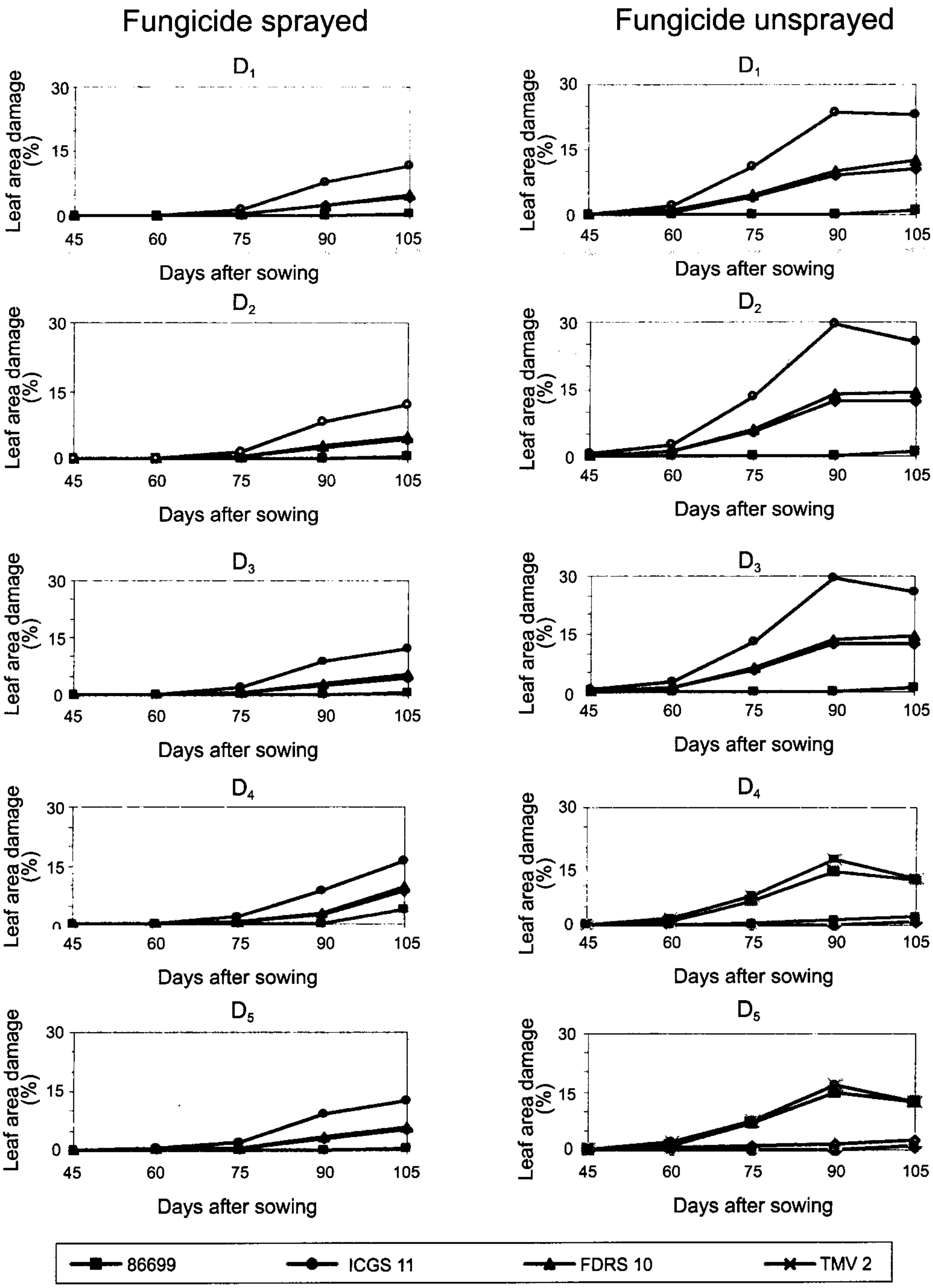

Fig. 2. Rust disease progress of four groundnut cultivars in different plant densities in fungicide, Kavach sprayed and unsprayed treatments; D_1=5 plants/m^2; D_2=10 plants/m^2; D_3=20 plants/m^2; D_4=30 plants/m^2; D_5=40 plants/m^2.

rust in all the plant densities of all four cultivars was found lower in fungicide sprayed plots than in unsprayed plots. The resistant cultivars ICGV 86699 and ICG (FDRS) 10 had significantly low rust disease in all plant densities in fungicide sprayed and unsprayed plots than the other cultivars. These two cultivars did not show significant differences in the severity of rust disease among plant densities between the fungicide sprayed and unsprayed treatments. Meanwhile, the susceptible cultivars ICGS 11 and TMV 2 had significantly higher disease in all plant densities in fungicide sprayed and unsprayed plots than the other two cultivars. Further, these two susceptible cultivars exhibited significantly more rust in higher plant densities (D_4, D_5) than in lower plant densities (D_1, D_2) in unsprayed plots. Severity of rust in resistant cultivars ICGV 86699 and ICG (FDRS) 10 remained low (-2.5%) throughout the crop

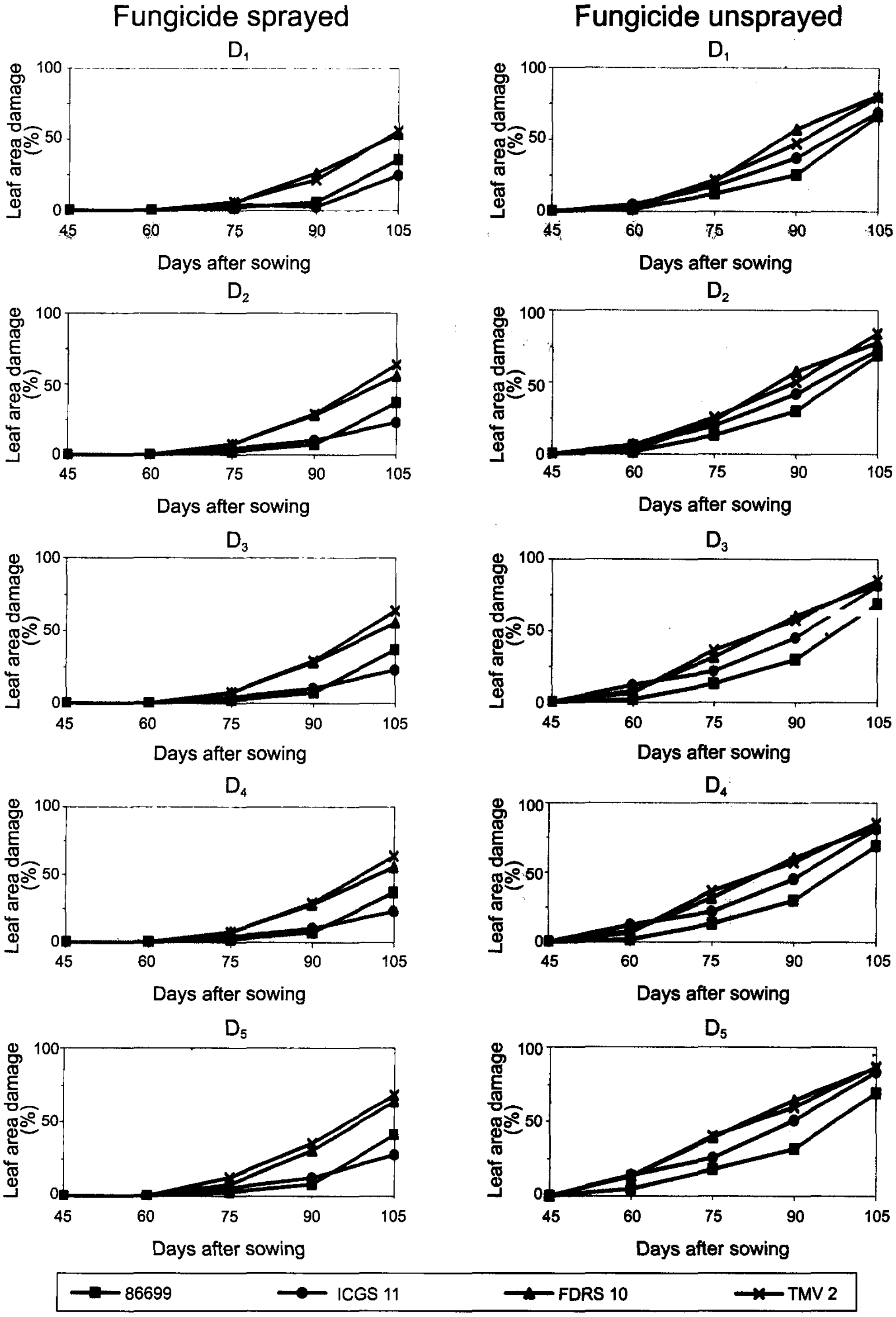

Fig. 3. Progress of percentage defoliation caused by late leaf spot of four groundnut cultivars in different plant densities in fungicide, Kavach sprayed and unsprayed treatments. D_1=5 plants/m^2; D_2=10 plants/m^2; D_3=20 plants/m^2; D_4=30 plants/m^2; D_5=40 plants/m^2.

season irrespective of plant densities in fungicide sprayed and unsprayed plots. All the plant densities of susceptible cultivars ICGS 11 and TMV 2 had less (<2%) disease up to 60 DAS in unsprayed plots and up to 75 DAS in sprayed plots. Thereafter, rust disease progressed and damaged up to 12% of the leaf area in all plant densities in unsprayed plots (Fig. 2).

Defoliation. Significant differences (P<0.05) in percentage defoliation were observed between fungicide sprayed and unsprayed treatments. All the cultivars had significantly less defoliation in all the plant densities in fungicide sprayed plots than in unsprayed plots. Maximum percentage defoliation was recorded in the highest plant density (D_5) in all the cultivars in fungicide sprayed and unsprayed plots. Minimum defoliation was recorded in all the plant densities of cultivars ICGV 86699 and ICGS 11 in the fungicide sprayed plots. Significant differences in percentage defoliation were not observed among the different population densities in cultivar ICGV 86699 in both fungicide sprayed and unsprayed plots. Though the cultivar ICGS 11 did not show any significant difference in defoliation among plant densities in fungicide sprayed plots, it had significantly less defoliation in lower plant densities (D_1, D_2) than in higher plant densities (D_3, D_4, D_5) in unsprayed plots. Cultivars ICG (FDRS) 10 and TMV 2 had significantly more percentage defoliation than the other cultivars in both fungicide sprayed and unsprayed plots. These two cultivars had higher defoliation in the highest plant density (D_5) than in the rest of the densities irrespective of fungicide protection. The percentage defoliation remained low (<10% in fungicide sprayed plots and <41.0% in unsprayed plots) up to 90 DAS in all the plant densities in resistant cultivar ICGV 86699. In contrast to cultivar ICGV 86699, percentage defoliation was up to 35% at 90 DAS in fungicide sprayed plots of ICGS 11, ICG (FDRS) 10, and TMV 2. Thereafter, the percentage defoliation progressed up to 105 DAS and reached -30% in cultivar ICGS 11, and up to 68% in ICG (FDRS) 10 and TMV 2 in fungicide sprayed plots. These three cultivars in unsprayed plots had defoliation of up to 40% at 75 DAS in all the plant densities, and thereafter defoliation increased and almost all the leaves defoliated by crop maturity (Fig. 3).

Haulm yield. Significant differences ($P<0.05$) in haulm yields were observed among cultivars, plant densities, and fungicide treatments. Significantly higher haulm yields were obtained in higher plant densities (D_4, D_5) in all the cultivars in fungicide sprayed plots than in unsprayed plots. The highest haulm yields were recorded in all plant densities in cultivar ICGV 86699, and the lowest in the cultivar ICG (FDRS) 10 in both fungicide sprayed and unsprayed plots. Haulm yields were significantly low in lower plant densities (D_1, D_2) than in higher plant densities (D_4, D_5) in all the cultivars irrespective of fungicide application. Haulm yields increased as the plant densities increased in all the cultivars in both fungicide sprayed and unsprayed plots. The highest haulm yields were obtained in the highest plant density (D_5) in all cultivars in both fungicide sprayed and unsprayed plots (Table 3).

Pod yield. Significant differences ($P<0.05$) were recorded among cultivars, plant densities, and fungicide treatments. Pod yields were significantly higher in higher plant densities (D_4, D_5) in fungicide sprayed plots than in unsprayed plots in all cultivars. Significantly higher pod yields were obtained in higher plant densities (D_4, D_5) than in lower densities (D_1, D_2) in all cultivars in both fungicide sprayed and unsprayed plots. Maximum pod yield was recorded in resistant cultivar ICGV 86699 in unsprayed plots, whereas, in moderately resistant ICGS 11, pod yields increased with the increase in plant densities in fungicide sprayed plots. In comparison with other test cultivars, TMV2 produced the lowest pod yields irrespective of plant densities in both fungicide sprayed and unsprayed treatments. In general, lower pod yields were recorded in lower plant densities; with increase in plant densities, pod yields increased in all cultivars in both fungicide sprayed and unsprayed plots. The highest plant density (D_5) gave the highest pod yields in all the cultivars in both fungicide sprayed and unsprayed plots (Table 4).

Discussion

The amount of rainfall and number of rainy days were almost similar throughout the crop growth in both years. This suggests that the two environmental factors were conducive for the development of high levels of LLS and rust diseases. In this study, the resistant cultivar ICGV

Table 3. Haulm yields of four groundnut cultivars in different population densities

Cultivars	Haulm yield (t ha^{-1})									
	D_1[a]		D_2		D_3		D_4		D_5	
	SP[b]	USP[c]	SP	USP	SP	USP	SP	USP	SP	USP
ICGV 86699	1.94	1.32	2.32	1.62	3.23	2.46	4.10	2.93	4.74	3.24
ICGS 11	1.00	0.98	1.47	1.33	2.19	1.59	2.67	2.05	3.14	2.17
ICG (FDRS)10	0.72	0.75	1.00	1.02	1.60	1.44	2.02	1.71	2.42	2.18
TMV 2	1.03	0.97	1.46	1.23	2.34	1.56	2.93	1.89	3.24	2.14
LSD ($P<0.05$)					0.41					

[a] D_1, 5 plants/m^2; D_2, 10 plants/m^2; D_3, 20 plants/m^2; D_4, 30 plants/m^2; D_5, 40 plants/m^2
[b] Fungicide, Kavach@ 2 g/l water and 800 liter chemical solution/ha sprayed at 15-day interval from 30 days after sowing
[c] Fungicide unsprayed

Table 4. Pod yields of four groundnut cultivars at different population densities

Cultivar	Pod yield (t ha^{-1})									
	D_1[a]		D_2		D_3		D_4		D_5	
	SP[b]	USP[c]	SP	USP	SP	USP	SP	USP	SP	USP
ICGV 86699	0.79	0.61	1.23	0.90	1.55	1.27	1.69	1.36	1.97	1.81
ICGS 11	0.58	0.43	1.06	0.66	1.80	0.85	2.18	1.11	2.56	1.17
ICG (FDRS)10	0.54	0.50	0.82	0.75	1.29	1.03	1.82	1.23	2.12	1.52
TMV 2	0.40	0.29	0.75	0.47	1.05	0.73	1.40	0.82	1.63	0.95
LSD (P<0.05)				0.22						

[a] D_1, 5 plants/m^2; D_2, 10 plants/m^2; D_3, 20 plants/m^2; D_4, 30 plants/m^2; D_5, 40 plants/m^2
[b] Fungicide, Kavach@ 2 g/l water and 800 liter chemical solution/ha sprayed at 15-day interval from 30 days after sowing
[c] Fungicide unsprayed

86699 had minimum infection of LLS and rust diseases in both fungicide sprayed and unsprayed plots. The severities of LLS and rust diseases were comparatively low in all the cultivars protected with fungicide than those without fungicide application. These results are consistent with the reports of Smith and Littrel (1980) and Subrahmanyam et al. (1984). Results of this study suggest that the severities of LLS and rust diseases were significantly higher in higher plant densities than in lower plant densities in all the cultivars. This is primarily because higher plant densities influence the micro-climate in favor of LLS and rust disease development. Wider spacing between rows and plants facilitate more aeration in the crop canopy, which results in the quick drying of the leaves making the condition less favorable for disease development. Thus, the duration of leaf wetness in wider spacing is reduced than that required for disease development like botrytis gray mold (*Botrytis cinerea*) in chickpea (Haware and McDonald, 1993; Pande et al., 1998). Chevaugeon (1952) and Ferrell et.al. (1967) reported that severity of LLS in groundnut increased as the in-row spacing decreased. Ghewande et al. (1986) also observed that LLS and rust severities were significantly more in closer spacing (higher plant densities) than in wider spacing (low plant densities). Results of this study are consistent with previous reports. However, contrary to these results, Yayock (1981) reported that the early maturing cultivar "Spanish 205" showed less LLS severity in higher plant densities than in lower densities.

The severity of LLS has profound influence on defoliation. Generally, the more the LLS, the more defoliation occurs. In this study, the resistant cultivar ICGV 86699 had significantly less LLS disease and, hence, less defoliation was recorded. Defoliation was lesser in all the cultivars in fungicide sprayed plots than in unsprayed plots. In fungicide-protected plots, there was a drastic reduction in LLS severity indicating that defoliation can be minimized by controlling lesion development on the leaves. Minimum defoliation was observed in moderately resistant ICGS 11 in fungicide sprayed plots. This confirmed earlier findings that when moderate levels of host plant resistance to foliar diseases were combined with economical levels of chemical control, foliar disease severities were lower and yields were higher (Pande et al., 2001).

Significant increase in haulm and pod yields was observed in all the cultivars in fungicide sprayed plots than in unsprayed plots (Subrahmanyam, 1984). Further, haulm and pod yields were significantly more in higher plant densities than in lower plant densities in both fungicide sprayed and unsprayed plots despite of the higher LLS and rust severities. The increase in haulm and pod yields were attributed to more plants per unit area in higher plant densities (D_4, D_5) than in lower plant densities (D_1, D_2, D_3). Maliro (1989) and Liang (1996) also found that higher plant densities gave higher pod yields. In this study, as the plant densities increased, haulm and pod yields were found to increase as well. These findings support the results obtained by Yayock (1981). Buchanan and Hauser (1980) also reported that closer spacing (higher plant densities) gave significantly more haulm and pod yields than wider spacing (lower plant densities). The highest haulm and pod yields were obtained in the highest population density (D_5) in all the cultivars in both fungicide sprayed and unsprayed plots. Similar findings were also reported by Shear and Miller (1960) and Marenah and Anderson (1977).

In general, in the semi-arid tropics of Asia and Africa where groundnut is primarily grown as a rainfed crop, farmers use lesser quantity of seeds than the recommended rate. Therefore, plant stand is always below optimum level which results in poor productivity per unit area. Also, farmers do not apply fungicides to protect the crop against LLS and rust diseases, which are the major constraints to groundnut production. Results of this study clearly suggest that an optimum plant density between 300,000 and 400,000 plants/ha (D_4, D_5) combined with fungicide protection against LLS and rust is needed to achieve maximum haulm and pod yields in groundnut.

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