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Long-term effect of nutrient management and rainfall on pod yield of groundnut (*Arachis hypogaea*) in groundnut–based cropping systems

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ABSTRACT

A field experiment was conducted from 1999 to 2008 on fixed site at the research farm of Directorate of Groundnut Research, Junagadh (Gujarat) to develop a sustainable nutrient management schedule for groundnut (*Arachis hypogaea* L.)–based cropping systems, and to find out the influence of seasonal rainfall on pod yield of groundnut. Combination of 14 treatments of inorganic nutrients (100% RDF and 50% RDF) and farmyard manure (5 t/ha) were applied to groundnut and the component crops of groundnut-wheat and groundnut-wheat [*Triticum aestivum* (L.) emend. Fiori & Paol]-greengram [*Vigna radiata* (L.) Wilczek] cropping systems. Integrated use of organic and inorganic nutrients (FYM 5 t/ha+50% RDF) to *kharif* groundnut recorded significantly higher pod yield (1,037 kg/ha) and the total system productivity in terms of groundnut equivalent yield (2,187 kg/ha) over the use of inorganic nutrients. This combination also recorded higher sustainable yield index and predictability over the use of inorganic nutrients across the experimental period. Among cropping systems, the total system productivity was significantly higher in groundnut-wheat-green gram cropping systems 2.34 + GPEY/ha with the integrated use of organic and inorganic nutrients. The rainfall in June had a significant effect on pod yield of groundnut when supplied with both organic and inorganic nutrients (FYM 5 t/ha+50% RDF). Depending upon the amount and period, rainfall received in the months of June and July had a positive effect on pod yield of groundnut, however, August and September rainfall showed negative effect.

Key words : Correlation, Groundnut, Nutrient, Rainfall, Regression, Sustainable yield index

Groundnut, the premier oilseed crop of India, occupies an area of about 6.7 million ha and contributes 7.3 million tonnes towards the oilseed production. India stands first in area and second in production, and fifth in productivity (1,000 kg/ha) after USA, China, Indonesia and Nigeria. The productivity of groundnut is low in India when compared with other countries mainly due to rain dependency (85%), monoculture (60%) and cultivation on marginal soils of low fertility. Groundnut is an energy rich crop and needs sufficient amount of nutrients and moisture to meet their requirement for growth and development and high yields. Sustainable groundnut production can be achieved by diversifying the groundnut cropping system and nutrient management practices (Dudhatra *et al*., 2002, and Balaguravaiah *et al*., 2005). Nutrient management for groundnut in monoculture and cropping system modes is an important aspect for sustainable production system in a long run. A thorough understanding of these factors and their interactions is critical in maximizing profitability of any cropping system. Kathmale *et al*. (2000) recorded the significantly higher groundnut-equivalent yield, net return and benefit:cost ratio of the groundnut-wheat cropping system with the application of organic and inorganic fertilizers together to *kharif* groundnut, and wheat crop. Groundnut responds well to the integrated nutrient management practices (Kausale *et al*., 2006). Besides the nutrient management, rainfall is also a crucial factor in rainfed groundnut production. The long-term relationship of rainfall and pod yield of groundnut in different time scales can be assessed and predicted by using statistical tools like correlation and regression analysis (Patel and Vaishnav, 2003 and Sahu *et al*., 2004). Since, most of the research work is concentrated on inorganic fertilizer management in groundnut as a sole crop where, the cause and effect of rainfall and nutrient management are aggravated more.

The present study was undertaken for 10 years to assess the long term effects of organic and inorganic nutrient management practices in groundnut and the fallow crops in the cropping systems on pod yield of groundnut, and to assess the performance of groundnut and nutrient management practices under variable rainfall during the period of

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experimentation from 1999 to 2008.

MATERIALS AND METHODS

A field experiment was conducted continuously on fixed site from 1999 to 2008 with three groundnut-based cropping systems *viz*., sole groundnut, groundnut-wheat and groundnut-wheat-green gram under different combinations of organic and inorganic nutrients management schedule on medium black calcareous soils at the farm of Directorate of Groundnut Research, Junagadh (Gujarat). The soils are medium black calcareous, low in organic carbon (0.49%) and available nitrogen (130 kg/ha), medium in available phosphorus (17 kg/ha) and potash (167 kg/ha). The groundnut was sown at 30 cm row-to-row and 10 cm plant-to-plant spacing on the onset of monsoon using seed rate 100 kg/ha. In groundnut-wheat cropping system, wheat was grown at 22.5 cm row-to-row using seed rate of 100 kg/ha during *rabi*, and green gram was grown as green manure crop after wheat harvest during summer. The earliest date of sowing of groundnut was 18 June during 2001 and farthest was 13 July during 2005, depending upon the date of onset of monsoon.

The rainfall received during 4 rainy months (June-September) of the crop season was recorded during each year from 1999-2008 (Table 1). The total crop seasonal rainfall showed a wide range of distribution from minimum 362 mm during 1999 to maximum 1,411 mm during 2007 with the mean of 930 mm and a coefficient of variation of 38%. The monthly rainfall ranges from 21 mm (2000) to 381 mm (2005) in June, 46 mm (2002) to 574 mm (2006) in July, 38 mm (1999) to 679 mm (2007) in August and 9 mm (2000) to 533 (2005) in September. A wide coefficient of variation (58 to 106%) was observed in the monthly rainfall received being; 62% in June, 58% in July, 74% in August and 106% in September of the reported period. The mean monthly rainfall received during 10 years varied from 175 mm during June to 301 mm during July. The seasonal rainfall showed two different scenarios, first from 1999 to 2002, and second after 2003 to 2008. During first scenario the mean rainfall received was only 560 mm (mean of 4 years) whereas, in the second scenario the rainfall received was more than double *i.e.* 1,176 mm (mean of 6 years). The rainfall received during of July was more (301 mm) with least variation (58%) than the other month's rainfall in the season.

Table 1. Monthly rainfall (mm) received during 1999 to 2008

Year /month	June	July	August	September	Total
1999	82	220	38	22	362
2000	21	309	193	9	532
2001	276	224	200	107	807
2002	276	46	120	95	537
2003	175	547	458	61	1,241
2004	152	201	476	95	924
2005	381	114	164	533	1,192
2006	76	574	299	136	1,085
2007	164	337	679	231	1,411
2008	149	436	111	509	1,205
Mean	175	301	274	180	930
CV (%)	62	58	74	106	38

Three cropping systems *viz*., sole groundnut, groundnut-wheat and groundnut-wheat-green gram were evaluated under 14 different combinations of organic and inorganic nutrients. A nutrient dose of 12.5 and 25 kg/ha of N and P, respectively for *kharif* groundnut and 120, 60 and 40 kg of N, P and K, respectively for wheat were recommended under rainfed condition of Gujarat. The green gram was grown as green manure crop and ploughed down at 30 days after sowing. The experiment was conducted in the split plot design with nutrients management of *kharif* groundnut (inorganic and inorganic+organic) in the main-plots; and cropping systems (sole groundnut, groundnut-wheat and groundnut-wheat-green gram) and their nutrient management in the sub-plots, and replicated three times. The treatment combinations were as follows; T_1- groundnut (100% RDF); T_2- groundnut (FYM 5 t/ha+50% RDF); T_3- groundnut (100% RDF)-wheat (100% RDF); T_4- groundnut (FYM 5 t/ha+50% RDF)-wheat (100% RDF); T_5- groundnut (100% RDF)-wheat (50% RDF); T_6- groundnut (FYM 5 t/ha+50% RDF)-wheat (50% RDF); T_7- groundnut (100% RDF)-wheat (FYM 5 t/ha+50% RDF); T_8- groundnut (FYM 5 t/ha+50% RDF)-wheat (FYM 5 t/ha+50% RDF); T_9- groundnut (100% RDF)-wheat (100% RDF)-green gram; T_{10}- groundnut (FYM 5 t/ha+50% RDF)-wheat (100% RDF)-green gram; T_{11}- groundnut (100% RDF)-wheat (50% RDF)-green gram; T_{12}- groundnut (FYM 5 t/ha+50% RDF)-wheat (50% RDF)-green gram; T_{13}- groundnut (100% RDF)-wheat (FYM 5 t/ha+50% RDF)-green gram; T_{14}- groundnut (FYM 5 t/ha+50% RDF)-wheat (FYM 5 t/ha+50% RDF)-green gram. Finely grounded farm yard manure (FYM) was applied 21 days before sowing of the crops as per treatments. Nitrogen, phosphorus and potassium were applied through urea, single super phosphate and muriate of potash, respectively as per treatments and recommendation to groundnut and wheat. Full doses of nitrogen and phosphorus were applied at the groundnut while ½ dose of nitrogen and full doses of phosphorus and potassium were applied to wheat as basal at the time of sowing and remaining ½ N was applied at the time of first irrigation.

The variation in pod yield during 10 years was assessed by calibrating treatment-wise regression analysis of yield as function of time period as:

$Y = \pm a \pm b$ (years)

The treatments of nutrient management and cropping

systems over 10 years were more precisely studied in the split plot design (Gomez and Gomez, 1985). The effects of main-plots (m_j), sub-plots (s_k), replications (r_i), interactions $(ms)_{jk}$ with main-plots error (m_{ij}) and sub-plots and interactions error (e_{ijk}) were laid out as:

$$Y_{ijk} = m + r_i + m_j + m_{ij} + s_k + (ms)_{jk} + e_{ijk,}$$

where Y_{ijk} is the observations of i^{th} replication, j^{th} main-plot and k^{th} sub-plot and m is the overall mean.

A more rigorous evaluation of the effect of organic and inorganic nutrients and cropping systems were made by calibrating treatment-wise multivariate regression model of yield as function of monthly rainfall of the crop-season between June and September) as:

$$Y = \pm a \pm b_1 (RF\ Jun) \pm b_2 (RF\ Jul) \pm b_3 (RF\ Aug) \pm b_4 (RF\ Sep)$$

The nutrient management treatments along with cropping systems were evaluated for superiority, based on sustainability yield index (SYI) as described by Singh *et al* (1990). Using mean yield (Y_{mean}) of treatments over 10 years, standard deviation (s) and maximum yield (Y_{max}) obtained among all the 140 values of the experiments, the SYI was calculated as:

$$SYI = (Y_{mean} - s)/Y_{max}$$

A treatment with maximum sustainable yield index was selected for attaining a maximum and sustainable crop yield under all the nutrient management and cropping system treatments.

RESULTS AND DISCUSSION

Pood yield

The yield attained under different treatments during 10 years (Table 2) ranged from 243 kg/ha under groundnut (100% RDF)-wheat (50% RDF) during 2006 to 1,802 kg/ha under groundnut (FYM 5 t/ha+50% RDF)-wheat (50% RDF)-green gram cropping system during 2003. The year-wise mean yield ranged from lowest 323 kg/ha in 2006 to highest 1,655 kg/ha in 2003 with a variation of 412%. The pod yield was decreased drastically from the year 2004 onwards. This might be due to high rainfall in July and August which match up to the pegging and pod formation stages of the crop. The treatment-wise mean yield over 10 years ranged from 899 kg/ha with a variation 38% under groundnut (100% RDF)-wheat (100% RDF)-green gram cropping system to 1097 kg/ha with a variation of 41% under sole groundnut (FYM 5 t/ha+50% RDF). The variation in the pod yield of groundnut was more due to time scale (years) than the treatment effects.

Sustainability yield index

Using mean yield and standard deviation of each treatment over 10 years and maximum yield of 1,802 kg/ha from groundnut (FYM 5 t/ha+50% RDF)-wheat (50% RDF)-green gram treatment, sustainable yield indices were derived for each treatment (Table 2). The sustainable yield index (SYI) values vary from lowest of 0.28 in groundnut

Table 2. Groundnut pod yield (kg/ha), predictability and SYI over 10 years

Year	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	Mean	CD (P=0.05)
1999	1,335	1,149	1,048	973	913	1,031	989	1,114	1,042	1,029	1,048	998	910	1,002	1,041	202
2000	1,167	1,680	1,293	1,769	1,304	1,668	1,345	1,538	930	1,117	1,061	1,160	1,073	1,213	1,308	253
2001	1,531	1,531	1,212	1,665	989	1,537	1,143	1,413	1,172	1,310	1,096	1,431	1,080	1,536	1,332	258
2002	1,109	1,236	896	1,158	845	1,052	925	1,011	788	891	855	890	831	921	957	169
2003	1,722	1,573	1,614	1,787	1,696	1,657	1,643	1,691	1,444	1,737	1,477	1,802	1,598	1,736	1,655	234
2004	517	420	440	519	551	558	521	533	433	417	476	514	434	452	484	113
2005	764	833	746	788	682	727	744	730	872	804	860	918	783	794	788	124
2006	339	407	323	373	243	355	247	316	296	350	309	384	259	327	323	71
2007	1,060	1,092	1,054	856	874	918	765	736	900	741	877	998	741	925	895	158
2008	897	1,048	1,040	1,072	965	1,043	1,200	930	1,112	1,233	1,078	1,240	1,204	1,206	1,090	263
Mean	1044	1,097	967	1,096	906	1,055	952	1,001	899	963	914	1,033	891	1,011		
CV (%)	41	41	40	46	44	43	43	44	38	43	36	40	43	43		
R^2	0.30	0.29	0.14	0.27	0.13	0.28	0.14	0.37	0.07	0.10	0.11	0.06	0.06	0.11		
SYI	0.34	0.36	0.32	0.33	0.28	0.34	0.30	0.31	0.31	0.30	0.32	0.34	0.28	0.32		

R^2 = coefficient of determination; SYI = sustainable yield index; T_1- groundnut (100% RDF), T_2- groundnut (FYM 5 t/ha+50% RDF), T_3- groundnut (100% RDF)-wheat (100% RDF), T_4- groundnut (FYM 5 t/ha+50% RDF)-wheat (100% RDF), T_5- groundnut (100% RDF)-wheat (50% RDF), T_6- groundnut (FYM 5 t/ha+50% RDF)-wheat (50% RDF), T_7- groundnut (100% RDF)-wheat (FYM 5 t/ha+50% RDF), T_8- groundnut (FYM 5 t/ha+50% RDF)-wheat (FYM 5 t/ha+50% RDF), T_9- groundnut (100% RDF)-wheat (100% RDF)-green gram, T_{10}- groundnut (FYM 5 t/ha+50% RDF)-wheat (100% RDF)-green gram, T_{11}- groundnut (100% RDF)-wheat (50% RDF)-green gram, T_{12}- groundnut (FYM 5 t/ha+50% RDF)-wheat (50% RDF)-green gram, T_{13}- groundnut (100% RDF)-wheat (FYM 5 t/ha+50% RDF)-green gram, T_{14}- groundnut (FYM 5 t/ha+50% RDF)-wheat (FYM 5 t/ha+50% RDF)-greengram
P=0.05

(100% RDF)-wheat (50% RDF)/groundnut (100% RDF)-wheat (FYM 5 t/ha + 50% RDF)-green gram to the highest of 0.36 in sole groundnut with the integrated use of nutrients (FYM 5 t/ha+50% RDF). The organic and inorganic nutrients applied together either to groundnut or wheat (T_2, T_4, T_6, T_8, T_{12} and T_{14}) except T_{10}, were recorded higher values of SYI as compared to inorganic nutrient treatments (T_1, T_3, T_5, T_7, T_9, T_{11} and T_{13}). Application of FYM 5 t/ha+50% RDF to groundnut recorded the highest SYI of 0.36 with the highest mean yield of 1,097 kg/ha and showed the predictability of 0.29. The predictability of obtaining higher pod yield of groundnut was also higher in the integrated use of organic and inorganic nutrients applied either to groundnut or wheat except treatment T2 and T12 in the cropping system than in the inorganic nutrients.

Superiority of nutrient management and cropping systems

The response of nutrient management and cropping systems on pod yield of groundnut and the total system productivity (TSP) in terms groundnut pod equivalent yield (GPEY kg/ha) were analysed using split plot design, and calculated least significant differences at P= 0.05. The results (Table 3) revealed that pod yield as well as TSP was significantly differing from year to year might be due to large variation in the total rainfall. The nutrient management significantly affected the pod yield of groundnut and TSP, and recorded higher with the application of integrated use of organic and inorganic nutrients over inorganic nutrients alone. The cropping systems and the nutrient management practices of component crops also differ significantly in pod yield of groundnut and TSP. The TSP was significantly higher in groundnut-wheat-green gram cropping systems (2,336 kg GPEY/ha) with the integrated use of organic and inorganic nutrients in both the crops followed by groundnut-wheat system (2.29 t GPEY/ha). The significant interaction among cropping systems and years were also recorded for pod yield of groundnut and TSP, whereas, nutrient management and cropping systems have significant interaction for TSP only.

Table 4. Effect of nutrient management and cropping systems on pod yield of groundnut and TSP over the years

Treatment	Pod yield (kg/ha)	Wheat grain yield (kg/ha)	GPEY (kg/ha)
Nutrient management in groundnut			
100% RDF	939	2,322	1,948
FYM 5 t/ha + 50% RDF	1,037	2,656	2,187
CD (P=0.05)	55		80
Cropping system			
Sole groundnut	1,070	0	1,070
Groundnut-wheat (100% RDF)	1,031	2,389	2,236
Groundnut-wheat (50% RDF)	980	2,293	2,143
Groundnut-wheat (FYM 5 t/ha + 50% RDF)	976	2,608	2,292
Groundnut-wheat (100% RDF)-greengram	930	2,595	2,243
Groundnut-wheat (50% RDF)-greengram	973	2,326	2,150
Groundnut-wheat (FYM 5 t+50% RDF)-greengram	951	2,721	2,336
SEm±	22	-	32
CD (P=0.05)	60	-	88

Table 3. Effect of nutrient management on total system productivity (GPEY kg/ha) of groundnut-wheat system

Treatment	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	Mean
T_1	1,335	1,167	1,531	1,109	1,722	517	764	339	1,060	897	1,044
T_2	1,149	1,680	1,531	1,236	1,573	420	833	407	1,092	1,048	1,097
T_3	2,789	1,909	1,949	1,627	2,278	1,688	1,988	2,128	2,580	2,116	2,105
T_4	2,499	2,494	2,467	2,282	2,578	1,827	2,418	2,500	2,224	2,388	2,368
T_5	2,326	1,664	1,550	1,461	2,233	1,803	1,963	2,020	2,532	1,878	1,943
T_6	2,599	2,387	2,321	2,196	2,510	1,959	2,245	2,418	2,646	2,149	2,343
T_7	2,554	2,054	2,025	1,926	2,404	2,024	2,227	2,276	2,297	2,515	2,230
T_8	2,646	2,393	2,357	2,357	2,551	1,721	2,333	2,368	2,568	2,246	2,354
T_9	2,516	1,683	2,110	1,738	2,128	1,822	2,354	2,293	2,553	2,325	2,152
T_{10}	2,273	2,144	2,126	2,178	2,483	1,838	2,530	2,484	2,666	2,616	2,334
T_{11}	2,343	1,600	1,742	1,649	2,034	1,490	2,129	2,042	2,189	2,153	1,937
T_{12}	2,681	2,046	2,220	2,078	2,593	1,788	2,537	2,511	2,586	2,585	2,362
T_{13}	2,229	1,915	1,910	1,916	2,252	1,767	2,325	2,267	3,004	2,634	2,222
T_{14}	2,465	2,226	2,330	2,272	2,556	1,855	2,528	2,449	3,072	2,758	2,451
SEm±	169	144	152	124	118	101	117	100	170	142	
CD (P=0.05)	492	417	441	360	342	294	339	282	496	414	

Table 5. Multivariate regression between groundnut pod yield (kg/ha) and monthly rainfall (mm)

Treatment	Regression model	R^2
T_1	Y=766 + 2.40* (Jun) + 0.87 (Jul) - 0.48 (Aug) - 1.52 (Sep)	0.30**
T_2	Y=1077 + 1.34 (Jun) + 0.53 (Jul) - 0.61 (Aug) - 1.15 (Sep)	0.18**
T_3	Y=726 + 1.24 (Jun) + 0.80 (Jul) - 0.28 (Aug) - 0.77 (Sep)	0.12**
T_4	Y=886 + 2.13* (Jun) + 1.06 (Jul) - 0.77 (Aug) - 1.51 (Sep)	0.24**
T_5	Y=672 + 1.10 (Jun) + 0.81 (Jul) - 0.20 (Aug) - 0.82 (Sep)	0.13**
T_6	Y=956 + 1.44 (Jun) + 0.77 (Jul) - 0.58 (Aug) - 1.27 (Sep)	0.20
T_7	Y=778 + 1.14 (Jun) + 0.87 (Jul) - 0.61 (Aug) - 0.68 (Sep)	0.13**
T_8	Y=895 + 1.73 (Jun) + 0.89 (Jul) - 0.75 (Aug) - 1.44 (Sep)	0.28**
T_9	Y=554 + 1.60 (Jun) + 0.86 (Jul) - 0.44 (Aug) - 0.42 (Sep)	0.15**
T_{10}	Y=491 + 2.28* (Jun) + 1.50 (Jul) - 0.81 (Aug) - 0.87 (Sep)	0.12**
T_{11}	Y=668 + 1.31 (Jun) + 0.73 (Jul) - 0.43 (Aug) - 0.48 (Sep)	0.12**
T_{12}	Y=461 + 2.38* (Jun) + 1.38 (Jul) - 0.44 (Aug) - 0.77 (Sep)	0.22**
T_{13}	Y=519 + 1.62 (Jun) + 1.13 (Jul) - 0.59 (Aug) - 0.51 (Sep)	0.17**
T_{14}	Y=524 + 2.42* (Jun) + 1.36 (Jul) - 0.60 (Aug) - 1.00 (Sep)	0.22**

*P,0.05; **P, 0.01; R^2, coefficient of determination; SE, prediction error; Jun, June; Jul, July; Aug, August; Sep, September.

Predication of yield through seasonal rainfall

The multivariate regression line fitted is of best-fit and showed significant (P=0.01) predictability (R^2) of the effect of seasonal rainfall (June -September) on pod yield of groundnut in all the treatments. The predictability of pod yield of groundnut with seasonal rainfall in different years was found in the range from 0.12 to 0.30 (Table 5). The estimate of prediction error (f) based on regression model was ranges from 416 kg/ha in groundnut (FYM 5 t/ha+50% RDF)-wheat (100% RDF)-green gram and/or in groundnut (100% RDF)-wheat (50% RDF)-green gram to 588 kg/ha in groundnut (FYM 5 t/ha+50% RDF)-wheat (100% RDF). The rainfall received in the month of June had a significant effect on pod yield in the treatments T_1, T_4, T_{10}, T_{12} and T_{14} when the groundnut supplied with both inorganic and organic nutrients (FYM 5 t/ha+50% RDF) except sole groundnut supplied with only inorganic nutrients. The multivariate regression analysis revealed that the magnitude of the effect of rainfall received in June and July was positive on pod yield of groundnut, whereas August and September rainfall had negative influence on the pod yield attained in all the 10 experiments. The magnitude of negative influence of rainfall in September is more than the rainfall in August, and also in the treatments received inorganic nutrients than, the organic treatments. Thus, the results revealed that pod yield of groundnut were significantly dependent on the rainfall and increase with the rainfall of June and July and decrease with the rainfall of August and September. Also, the groundnut responds more positively to the rainfall when grown in the groundnut-wheat-greengram cropping system and supplied with both organic and inorganic nutrients.

REFERNCES

Balaguravaiah, D., Adinarayana, G., Prathap, S. and Reddy, T.Y. 2005. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rainfed groundnut in Alfisols. *Journal of the Indian Society of Soil Science* **53**(4): 608–611.

Dudhatra, M.G., Vaghani, M.N., Kachot, N.A. and Asodaria, K.B. 2002. Intergarted input manageement in groundnut (*Arachis hypogaea*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **47**(4): 482–486.

Gomez, K.A. and Gomez, A.A. 1985. *Statistical Procedures for Agricultural Research*. John Wiley & Sons Inc., New York.

Kathmale, D.K., Khadtare, S.V., Kamble, M.S. and Patil, R.C. 2000. Intergated nutrient management in groundnut (*Arachis hypogaea*)-wheat (*Triticum aestivum*) cropping system on vertisols of western Maharashtra plain zone. *Indian Journal of Agronomy* **45**(2): 248–252.

Kausale, S.P., Kote, G.M., Awasarmal, V.B. and Borse, N.S. 2006. Effect of INM on nodulation, growth and yield of summer groundnut. *Annals of Plant Physiology* **20**(2): 226–229.

Patel, J.S. and Vaishnav, M.R. 2003. Evaluation of different approaches to study the effect of rainfall on groundnut in dry farming areas of Gujarat. *Journal of Agrometeorology* **5**(1): 76–83

Sahu, D.D., Patra, B.K. and Patoliya, B.M. 2004. Effect of sowing time and rainfall distribution on groundnut yield. *International Arachis Newsletter* **24**: 39–42.

Singh, R.P., Das, S.K., Rao, U.M.B. and Reddy, M.N. 1990. *Towards Sustainable Dryland Agricultural Practices. Bulletin*, Central Research Institute for Dryland Agriculture, Hyderabad, pp. 5–9.