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Polythene mulching and fertigation in peanut (*Arachis hypogaea*): Effect on crop productivity, quality, water productivity and economic profitability

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ABSTRACT

Enhancing crop productivity, profitability and saving of precious natural resources (soil and water), is a matter of prime concern. With this backdrop, a field experiment was conducted during *kharif* 2011-2013 at Junagadh (Gujarat) with mulching and fertigation treatments in peanut (*Arachis hypogaea* L.) in split plot design with three replications. Polythene mulching significantly enhanced pod, haulm, kernel and oil yields over no mulch. Moreover, it also ensured higher partial factor productivity, water productivity, net return, soil moisture content (at flowering, pegging, and pod formation stages of peanut), and N, P and K uptake over no mulch. Amongst the fertigation treatments, F_2 was found better in improving pod, haulm, kernel and oil yields, and P uptake over F_1. However, maximum partial factor productivity was recorded under F_1 while water productivity, net return, soil moisture content, and N and K uptake under F_4. Alkaline phosphatase activity was better sustained in F_3 over F_1 and F_2. Soil N, P and K status improved under mulching and fertigation treatments. Our study revealed the possibility of adoption of mulch and fertigation at farmers' fields implying judicious use of water and nutrients assuring a good yield and net profit.

Key words: Fertigation, Peanut, Polythene mulch, Water productivity, Yield

Globally, peanut (*Arachis hypogaea* L.) is the fourth most important source of edible oil and third most important source of protein. In India, peanut is one of the important oilseed crops and occupies an area of 5.86 million ha with the production of 8.27 million tonnes and productivity of 1411 kg/ha (2010-11) (Anonymous 2012) which is quite low as compared to other countries. Among the various factors that limit the productivity of peanut, water stress, nutrient deficiency and competition of weeds are important. Therefore, use of polythene mulching along with efficient use of available water and fertilizer are highly critical for improving the crop productivity in the country. Polythene film mulching played a major role in crop production by creating mechanical protection at the soil surface and favourable microclimate in terms of temperature distribution, retention of humidity and the supply of CO_2 to the stomata for enhanced fixation in photosynthesis (Maeda-Martinez 1989, Otsuki *et al*. 2000, Singh *et al*. 2004, Nalayini *et al*. 2009, Pramanik *et al*. 2015). The beneficial effects of polythene mulch for enhanced utilization of water and fertilizer, and weed control (Fortnum *et al*. 2000, Kashi *et al*. 2004, Ramakrishna *et al*. 2006; Mahajan *et al*. 2007, Nalayini *et al*. 2009) have already been worked out. Though the use of polythene mulch is very common in high value vegetable crops, yet its usage has not been fully exploited in peanut. However, the main concern of its usage remains in disposal of waste and the associated environmental impact (Lamont 1993).

The problem of water scarcity has tremendously increased due to ever increasing human and livestock population in arid and semi-arid regions. It is, therefore, adoption of modern irrigation techniques which are simple, easy to operate and increase the efficiency of water usage, are very important. Among these, drip irrigation is the most effective way to supply water and nutrients to the plant due to its precise and direct application of water in the root zone. Similarly, in fertigation, fertilizers are applied through emitters directly in the zone of maximum root activity and consequently fertilizer-use efficiency can be improved over conventional method of fertilizer application. Fertilizer requirement can be reduced by 15-25% with fertigation through drip without affecting the yield (Hongal and Nooli 2007). However, meagre information is available, when polythene mulch and fertigation are applied in combination to judge the crop productivity, quality, water productivity,

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soil nutrient balance as well as economic sustainability in field crops like peanut. Since peanut is widely cultivated in western parts of India (Gujarat, Maharashtra, Rajasthan), and this part is often faces moderate to severe drought, or scanty rainfall, preserving the rainwater always demands a fair attention among crop growers. In one hand, fertigation optimises the loss of irrigation water and nutrients; whereas in other hand, ploythene mulch checks the evaporation loss and holds the soil moisture for a longer run. In this backdrop, the present investigation was aimed with a unique set of treatments (mulching and drip fertigation) to study the comparative suitability of polythene mulch and fertigation for maintaining overall agronomic sustainability (in terms of yield potentiality, economics, water productivity and soil nutrient balance) in *kharif* peanut.

MATERIALS AND METHODS

A field experiment was conducted for three consecutive *kharif* seasons during 2011-2013 at the research farm of Directorate of Groundnut Research (longitude 70°36'E, latitude 21°31'N, elevation of 60 m above MSL), Junagadh, Gujarat, India. The soil of the experimental site was Typic Haplustepts, moderately calcareous and slightly alkaline (pH 7.7), low in organic carbon (4.8 g/kg) and available nitrogen (125.4 kg/ha) and medium in phosphorus (18.6 kg/ha) and potassium (223.1 kg/ha) status. The climate of the region is semi-arid, characterized by hot and dry summer, fairly cold and dry winter, and warm and moderately humid monsoon. The rainfall generally commences in the second fortnight of June and ends by September, practically little or no rainfall was observed at other time of the year. Partial failure of monsoon once in three to four years is of common occurrence in this region.

Seasonal weather parameters including minimum and maximum temperature and relative humidity, rainfall, bright sunshine hours and open pan evaporation were obtained from Agromet Observatory, Junagadh Agricultural University, Junagadh for the crop growth period for individual three seasons. Mean weekly maximum temperature ranged from 29.9-36.5^{0}C, 29.9-37.7^{0}C and 28.5-35.2^{0}C during 2011, 2012 and 2013, respectively. Whereas, corresponding minimum temperature ranged from 22.8-26.3^{0}C, 15.6-27.2^{0}C and 19.0-25.6^{0}C. During the crop growth season, maximum relative humidity ranged from 66-95%, 51-95% and 76-97% during 2011, 2012 and 2013, respectively. Whereas, the corresponding values of minimum relative humidity ranged from 36-88%, 21-85% and 32-93%. Open pan evaporation was observed to be highest in 41st week (5.9 mm/day) in 2011, 26th week (7.5 mm/day) in 2012, and 43rd week (5.1 mm/day) in 2013. Bright sunshine hours were maximum in 40th week (13.6 h) in 2011, 43rd week (9.7 h) in 2012 and 43rd week (9.6 h) in 2013. The crop received 925.4, 340.8 and 754.4 mm rainfall during *kharif* 2011, 2012 and 2013, respectively.

The experiment, comprised two mulching treatments, viz.M_1, No mulch and M_2, Polythene mulch, allotted to main plots and five fertigation schedules, viz. F_1, Drip fertigation with 50% RDF, F_2, Drip fertigation with 75% RDF, F_3, Drip fertigation with 100% RDF, F_4, Drip irrigation and soil application of 100% RDF and F_5, Furrow irrigation and soil application of 100% RDF as control, allotted to sub-plots, was carried out in split plot design with three replications at the same site. Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate and muriate of potash, respectively. In F_4 and F_5 treatments, the recommended doses of nitrogen, phosphorus and potassium were applied at the time of sowing. Whereas in drip fertigation treatments (F_1 to F_3), N, P and K as per treatments were applied in three equal splits, i.e. at sowing, 20 and 40 days after germination through drip. The crop was grown on raised beds of 60 cm width leaving 30 cm furrows on either side. Polythene film (5 μ thick, 90 cm width) was spread in the mulch treatment prior to sowing. The crop spacing (R–R×P–P) was maintained at 20 cm × 20 cm (mulched plots) and 20 cm × 10 cm (non-mulched plots) in the raised beds. Peanut TG 37A was sown on 2nd July, 28th June and 19th July and harvested at 109, 127 and 102 days after sowing during 2011, 2012 and 2013, respectively. In drip irrigation plots, one lateral was placed for three rows on each raised bed. The water discharged from each dripper was at rate of 4 l/h. On an average, the crop received 804.7, 808.4, 816.6, 802.1 and 1107.3 mm water (irrigation water and rainfall) in F_1, F_2, F_3, F_4 and F_5 treatments, respectively during the crop growth period. Weeds were managed by pre-emergence spray of oxyfluorfen @ 0.25 kg/ha.

The plant height and dry weight, each were recorded at 30 and 60 DAS, and at harvest by randomly selected three plants/treatment. SPAD chlorophyll meter reading (SCMR) was recorded from second fully expanded leaf from the apex at 30 and 60 DAS, by taking three random observations/treatment in the morning hours (08.00-9.30 h) by Minolta SPAD chlorophyll meter. The leaf area was measured from the average of three leaves by portable leaf area meter. Leaf area index (LAI) was calculated by dividing the total leaf area with the ground area/plant at 60 and 90 DAS. The selected plant samples were partitioned into leaf and stem and oven-dried at 65°C; the weight was recorded as dry matter accumulation by leaves and total plant. The nodules/plant were counted at 30, 60 and 90 DAS.

The roots of three randomly selected plants were excavated up to 15 cm soil depth at 90 DAS. For measuring root volume, entire root portion of the plant was cut and inserted in a cylinder of known quantity of water and the root volume (cm^3/plant) was measured by water displacement method. Roots were oven-dried and weight was recorded and expressed as root weight/plant. Relative leaf water content (RWC) was estimated by recording the fresh and turgid weight, and dry weight at 45 and 90 DAS (Weatherley 1950).

Yield attributing parameters, viz. number of pegs/plant (30 and 60 DAS), number and weight of mature and immature pods/plant (at harvest), 100-kernel weight (at harvest) and shelling out-turn (at harvest) were recorded. At physiological maturity, the crop was harvested manually and sun-dried for 4-5 days in the field and then the total biomass yield was recorded. After stripping, cleaning and sun-drying, the pod yield was recorded and expressed as kg/ha. Haulm yield of each treatment was determined by subtracting pod yield from total biomass yield.

Partial factor productivity (PFP) is calculated as the ratio of pod yield to applied nutrients and expressed as kg pods/kg nitrogen, phosphorus, and potassium (NPK) applied. The amount of water applied to each treatment was measured with the help of water meter. Water productivity (WP, kg/m^3) was calculated by dividing pod yield (dry weight basis) with the quantity of water applied including rainfall received.

At harvest, plant samples were collected, oven-dried (at 65 °C), and analyzed for N, P and K with standard procedures. The uptake of N, P and K by peanut pods and haulm was calculated by multiplying the pod and haulm yields with their respective nutrient concentrations. Protein, oil, and moisture contents in the kernels were determined with near-infrared (NIR) analyzer. The oil yield was worked out by multiplying kernel yield and oil content recorded in each treatment.

Soil moisture content was estimated at flowering, pegging, pod formation, pod development and maturity stages of peanut crop on oven dry-weight basis from 0-15 cm soil depth. For soil nutrient analysis, initial soil samples were collected from 0-15 cm depth from five sites in the experimental field. After the third cropping cycle, soil samples were collected from each plot (0-15 and 15-30 cm depths). A portion of soil sample (0-15 cm) was kept at 4^0C in plastic bags in a refrigerator. Whereas other portion was used for analysis of available N, P and K by following standard procedures. Treatment-wise N, P and K balance sheets indicating the available nutrients in the soil at initial stage, nutrients added for raising the crop, nutrients uptake by the crop, nutrients left in the soil after the harvesting, actual gain/loss over initial status and apparent nutrient balance in the soil for 0-15 cm depth were calculated. Soil samples (0-15 and 15-30 cm depths) were also analyzed for pH, electrical conductivity and bulk density. The moist soil samples were taken out from the refrigerator, allowed to reach to room temperature, passed through 2-mm sieve and used for assaying enzymatic activities. A sub-sample of moist soil sample was used for determination of moisture content so as to express the results on oven dry-basis.

Dehydrogenase activity of the soil sample at harvest was determined by following the procedure of Casida *et al*. (1964). Urease activity of the soil sample at harvest was determined by following the procedure of Chhonkar *et al*. (2007). Phosphatase activity of the soil sample at harvest was determined by following the procedure of Tabatabai and Bremner (1969).

The economics of different treatments was calculated by taking into account the various inputs required and outputs realized as per the prevailing cost of inputs and outputs during the respective years. Gross return was worked out based on the prices of main produce (pod) and by-product (haulm) of the crop prevailing during each year. Net return was estimated by deducting the total cost of cultivation from gross return, and benefit cost ratio (return per rupee invested) by dividing gross return with the cost of cultivation.

All the data obtained for three consecutive years of study were subjected to pooled analysis for comparison and statistically analyzed using the F-test procedure given by Gomez and Gomez (1984). The critical difference (CD) values at $P \leq 0.05$ were used for determining the significance of differences between treatment means.

RESULTS AND DISCUSSION

Growth and yield attributes, and yield of peanut

Effect of mulching: Polythene mulching resulted in higher growth attributes, viz. plant height (30 and 60 DAS, and harvest), dry weight of leaves (60 and 90 DAS) and plants (30 and 60 DAS, and harvest), SCMR (60 DAS), nodules/plant (30, 60 and 90 DAS) and leaf area index (60 and 90 DAS) (Table 1). However, few other growth attributes remained unchanged due to polythene mulching, viz. SCMR (30 DAS), root dry weight/plant (90 DAS), root volume/ plant (90 DAS) and relative leaf water content (45 and 90 DAS) (Table 1). The positive effect on plant height was due to reduced leaching of nutrients, weed problems and higher soil water content (Anikwe *et al*. 2007). Ramakrishna *et al*. (2006) and Jain *et al*. (2017) have also reported taller peanut plants under polythene and straw mulched plots than in the unmulched plots.

Polythene mulch increased leaf dry weight by 33.3 and 30.5% at 60 and 90 DAS, respectively, and total dry matter accumulation enhanced up to the extent of 31.1, 24.2 and 12.1% at 30 and 60 DAS, and at harvest, respectively, over no mulch. Hu *et al*. (1995) observed that total biomass under polythene mulched groundnut was 21% higher at peak growing stage, 22% higher at vegetative stage, and 31% higher at reproductive stage over the control. Subrahmaniyan *et al*. (2008a) and Jain *et al*. (2017) also reported that dry matter accumulation between polyethylene film mulches and non-mulched peanut differed markedly at all the crop growth stages.

SPAD chlorophyll meter reading, as indicator of leaf chlorophyll content was studied under the present experiment. It was also significantly higher under polythene mulching (36.7) as compared to no-mulching (35.1) at 60 DAS. The leaf area index due to polythene mulch was 3.14 and 3.96 as compared to 2.48 and 3.08 under no-mulched conditions at 60 and 90 DAS, respectively (Table 1). It was a cumulative effect of better growth environment, higher nutrient mobilization and better partitioning to shoot system that resulted in broader leaves.

The number of nodules/plant was also recorded higher in polythene mulched peanut over non-mulched peanut from 19.7 to 23.6, 36.2 to 41.7 and 51.3 to 56.4/plant at 30, 60 and 90 DAS, respectively. Higher assimilation of photosynthates and better partitioning of assimilates under mulching resulted in superior reproductive structures as

Table 1 Effect of mulching and fertigation on growth attributes of *kharif* peanut (Mean data for three years)

Treatment	Plant height (cm)			Plant dry weight (g/plant)			Leaf dry weight (g/plant)		SCMR		Nodules/plant (No.)			RWC (%)		Root volume (cm^3)	Root dry weight (g/ plant)	Leaf area index	
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	60 DAS	90 DAS	30 DAS	60 DAS	30 DAS	60 DAS	90 DAS	45 DAS	90 DAS	90 DAS	90 DAS	60 DAS	90 DAS
Mulching																			
M_1: No mulch	13.1	25.9	28.2	1.90	7.89	10.59	4.8	5.9	34.1	35.1	19.7	36.2	51.3	91.4	88.5	1.33	0.44	2.48	3.08
M_2: Polythene mulch	15.6	28.8	31.9	2.49	9.80	11.87	6.4	7.7	36.1	36.7	23.6	41.7	56.4	92.6	90.8	1.47	0.48	3.14	3.96
LSD (P≤0.05)	0.7	1.6	2.6	0.14	0.43	0.71	0.7	0.7	NS	1.36	2.3	1.9	3.1	NS	NS	NS	NS	0.29	0.70
Fertigation																			
F_1: DF with 50 % RDF	13.3	24.6	27.4	2.01	7.89	10.37	5.2	5.9	34.1	35.1	18.9	35.2	47.1	92.5	87.6	1.28	0.42	2.25	2.99
F_2: DF with 75% RDF	14.2	26.9	29.6	2.17	8.86	11.44	5.6	7.0	35.3	35.4	21.8	38.8	53.6	91.4	89.9	1.40	0.46	2.98	3.99
F_3: DF with 100% RDF	14.4	28.2	30.9	2.18	8.92	11.65	5.5	6.9	34.9	36.0	21.8	39.6	54.4	92.7	89.7	1.42	0.48	2.96	3.53
F_4: DI + soil application of 100% RDF	14.9	28.7	31.1	2.36	9.33	11.36	5.9	7.2	35.7	35.8	22.2	40.0	57.3	92.2	89.0	1.40	0.46	2.97	3.76
F_5: FI + soil application of 100% RDF	15.0	28.3	31.3	2.26	9.24	11.33	5.6	6.9	35.4	37.2	23.5	41.1	56.8	91.3	91.8	1.52	0.49	2.89	3.33
LSD (P≤0.05)	0.8	2.0	1.9	0.24	0.94	0.71	NS	0.9	NS	1.80	2.3	3.6	3.9	NS	2.2	NS	NS	0.35	0.87

DF: Drip fertigation; DI: Drip irrigation; FI: Furrow irrigation; NS: Non-significant; SCMR: SPAD chlorophyll metre reading; RWC: Relative leaf water content.

visible by the production of more pegs (14.2/plant at 60 DAS) and mature pods (13.1/plant at harvest) (Table 2). The mulched peanut also produced heavier pods (10.2 g/ plant) over control. On the other hand, non-mulched plots recorded higher number and weight of immature pods (2.6 and 0.6 g/plant, respectively). This is in accordance with Jain *et al*. (2017) who reported more reproductive peanut pods in polythene mulched plots.

Due to better seed filling under the unstressed environment of mulching, 100-kernel weight was higher under polythene mulch (37.6 g) as compared to control (35.8 g). Shelling out-turn did not differ significantly under mulching treatment. The favourable micro-climate under mulching increased pod, haulm and kernel yields by 23.5, 20.7 and 27.2%, respectively over no mulch (Table 2). Similar increase in yield due to mulching was reported in peanut (Ramakrishnan *et al*. 2006, Jain *et al*. 2017). Positive correlation of sound seeds, 100-seed weight and shelling ratio with seed yield of peanut was also observed in previous study (Cheong *et al*. 1995).

Effect of drip fertigation: Successive increase in fertigation levels from 50 to 100% RDF produced taller plants at 30 and 60 DAS, and at harvest but significant response was obtained up to drip fertigation with 75% RDF and was at par to drip fertigation with 100% RDF, drip irrigation and soil application of 100% RDF, and furrow irrigation and soil application of 100% RDF (Table 1). At 30 DAS, plant dry weight was significantly higher under drip irrigation and soil application of 100% RDF over drip fertigation with 50% RDF and was at par with other treatments. On the other hand, plant dry weight increased significantly up to drip fertigation with 75% RDF, and was at par with drip fertigation with 100% RDF, drip irrigation and soil application of 100% RDF, and furrow irrigation and soil application of 100% RDF at 60 DAS and harvest. Leaf dry weight also increased significantly up to drip fertigation with 75% RDF and was at par with rest of the treatments at 90 DAS. However, it did not improve significantly at 60 DAS due to any fertigation levels. Significantly higher SCMR values were recorded under furrow irrigation and soil application of 100% RDF over drip fertigation with 50 and 75% RDF and was at par with other treatments at 60 DAS, whereas none of the fertigation levels had any significant effect on SCMR at 30 DAS, root weight/plant and root volume/plant at 90 DAS. Number of nodules/plant increased significantly up to drip fertigation with 75% RDF at 30, 60 and 90 DAS and was at par with other treatments. Similarly, leaf area index was also significantly increased due to drip fertigation with 75% RDF and was at par with other treatments at 60 and 90 DAS. Hebbar *et al*. (2004), and Jain and Meena (2015) also reported significantly higher total dry matter with fertigation. Relative leaf water content did not differ significantly due to fertigation at 45 DAS but significantly higher RWC was recorded under furrow irrigation and soil application of 100% RDF over drip fertigation with 50% RDF, and drip irrigation and soil application of 100% RDF at 90 DAS and was at par with rest of the treatments. However, it showed declining trend with advancement of age towards maturity.

Significantly higher number of pegs/plant were recorded under the treatment drip irrigation and soil application of 100% RDF over all the treatments at 30 DAS while a progressive increase in drip fertigation levels from 50 to 75% RDF significantly increased the number of pegs/plant and thereafter, it was at par with other treatments at 60 DAS. Number and weight of mature pods/plant increased up to 100% RDF through drip fertigation but significant response was obtained up to 75% RDF through drip fertigation and was at par with rest of the treatments (Table 2). On the other hand, number and weight of immature pods/plant, 100-kernel weight and shelling out-turn were not affected significantly due to various fertigation schedules. The fertigation provided better conducive conditions for better uptake of nutrients and in turn helped the plants to boost their growth leading to the development of yield attributes through supply of more photosynthates towards the reproductive sink compared to conventional method of soil application of nutrients (Jayakumar *et al*. 2014).

Successive increase in drip fertigation levels from 50 to 75% RDF significantly enhanced the pod, haulm and kernel yields of peanut and was at par to drip fertigation with 100% RDF, drip irrigation and soil application of 100% RDF, and furrow irrigation and soil application of 100% RDF (Table 2). The drip fertigation with 75% RDF significantly improved the pod yield by 12.0%, haulm yield by 18.9% and kernel yield by 13.0% over drip fertigation with 50% RDF. In fact, crop yield is a complex entity which depends on complementary interaction between vegetative and reproductive growth of the crop. Marked increase in economic yield appeared to be on account of beneficial effect of fertigation on growth and yield attributes of the crop (Table 1 and 2).

Kernel quality

Use of polythene mulch and fertigation did not influence the protein and moisture contents in peanut kernels over non-mulched peanut. On the other hand, polythene mulched peanut recorded 1.0% significantly higher oil content over non-mulched peanut (Table 2). Successive increase in drip fertigation levels up to 75% RDF significantly enhanced the oil content by 2.2% over drip fertigation with 50% RDF and was at par with rest of the treatments. Oil yield is a function of oil content and kernel yield, which was found to be significantly higher by 27.7% in polythene mulched peanut over control. Successive increase in drip fertigation levels up to 75% RDF significantly enhanced the oil yield by 14.8% over drip fertigation with 50% RDF and was at par with rest of the treatments (Table 2).

Partial factor productivity and water productivity

Use of polythene mulch registered higher partial factor productivity (34.1 kg pods/kg NPK) as compared to no mulch (27.6 kg pods/kg NPK) owing to higher pod yield in the favourable soil conditions (Fig 1). Further, the polythene

Table 2 Effect of mulching and fertigation on yield attributes, yield, economics and quality of *kharif* peanut (Mean data for three years)

Treatment	Pegs/plant (No.)		Mature pods/ plant (No.)	Immature pods/plant (No.)	Weight of mature pods (g/ plant)	Weight of immature pods (g/ plant)	100-kernel weight (g)	Shelling out-turn (%)	Pod yield (kg/ ha)	Haulm yield (kg/ha)	Kernel yield (kg/ ha)	Net return (₹/ha)	Benefit cost ratio	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Moisture content (%)
	30 DAS	60 DAS															
Mulching																	
M_1: No Mulch	4.1	12.3	9.7	2.6	7.9	0.6	35.8	61.7	1690	2825	1047	30851	1.86	50.8	537	26.9	7.42
M_2: Polythene mulch	5.1	14.2	13.1	2.2	10.2	0.5	37.6	63.7	2087	3410	1332	40792	1.81	51.3	686	27.7	7.58
LSD ($P \leq 0.05$)	NS	0.4	1.0	NS	0.8	NS	0.8	NS	107	370	55	4107	NS	0.3	25	NS	NS
Fertigation																	
F_1: DF with 50 % RDF	4.4	12.1	9.8	2.2	7.8	0.5	36.0	62.5	1704	2692	1081	28643	1.67	50.2	549	27.3	7.47
F_2: DF with 75% RDF	4.4	13.5	11.3	2.4	9.4	0.6	36.9	63.2	1909	3202	1222	36807	1.83	51.3	630	27.7	7.56
F_3: DF with 100% RDF	4.6	13.3	12.1	2.3	9.6	0.6	37.0	61.8	1924	3223	1189	36220	1.81	51.1	613	27.0	7.52
F_4: DI + soil application of 100% RDF	5.3	13.9	11.4	2.4	8.9	0.5	37.0	63.1	1976	3330	1244	38965	1.88	51.4	642	27.6	7.55
F_5: FI + soil application of 100% RDF	4.4	13.4	12.3	2.7	9.5	0.6	36.5	63.0	1930	3140	1214	38473	2.00	51.2	624	26.9	7.40
LSD ($P \leq 0.05$)	0.7	1.2	1.3	NS	0.9	NS	NS	NS	83	306	73	3592	0.08	0.9	40	NS	NS

DF: Drip fertigation; DI: Drip irrigation; FI: Furrow irrigation; NS: Non-significant.

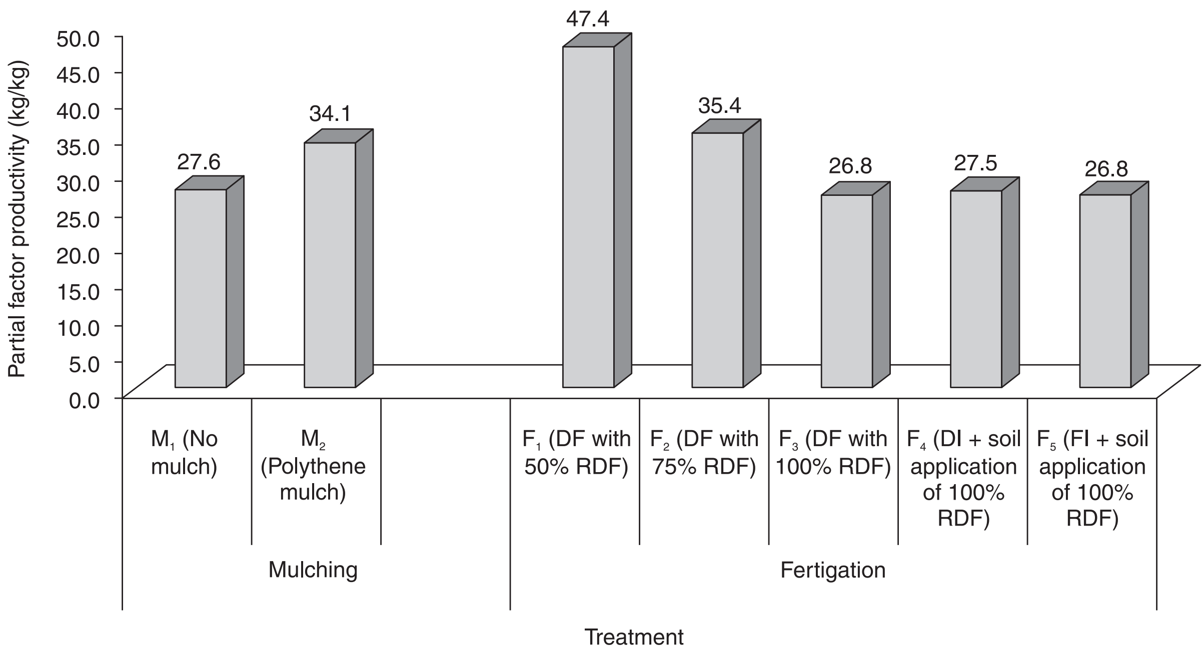

Fig 1 Effect of mulching and fertigation on partial factor productivity (NPK) of *kharif* peanut (mean of 2011-13).

mulch recorded higher water productivity of peanut (0.24 kg pods/m^3) over no mulch (0.19 kg/m^3) due to higher pod yield and less water use by peanut under polythene mulch (Fig 2).

The maximum partial factor productivity (47.4 kg pods/kg NPK) was recorded with the application of 50% RDF through drip fertigation and showed declining trend with successive increase in drip fertigation levels up to 100% RDF (26.8 kg pods/kg NPK) and was at par with furrow irrigation and soil application of 100% RDF (26.8 kg pods/kg NPK) (Fig 1). In general, water productivity was higher under drip irrigation as compared to furrow (surface) method of irrigation. Maximum water productivity (0.25 kg/m^3) was registered under soil application of 100% RDF and drip irrigation while minimum (0.17 kg/m^3) under furrow irrigation and soil application of 100% RDF (Fig 2).

Economics

Significant increase in net return was obtained under polythene mulching (Table 2). Economics showed the higher return from peanut grown in polythene mulch (₹ 40792/ha) over non-mulched condition (₹ 30851/ha). Drip fertigation up to 75% RDF significantly enhanced net return and recorded additional net return of ₹ 8164/ha over drip fertigation with 50% RDF and was at par with other treatments. However, benefit cost ratio did not differ significantly by mulching but significantly higher benefit cost ratio (2.00) was registered with soil application of 100% RDF under furrow irrigation.

Soil moisture status

Use of polythene mulch significantly improved soil moisture content at flowering, pegging, and pod formation

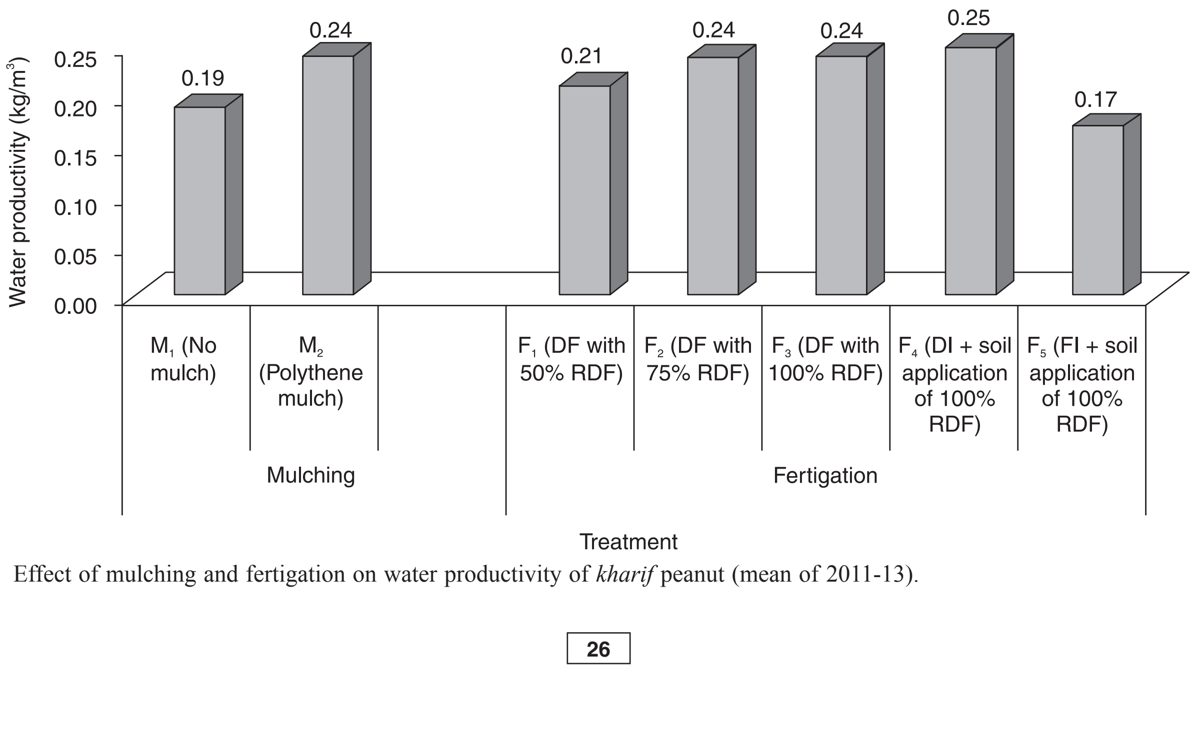

Fig 2 Effect of mulching and fertigation on water productivity of *kharif* peanut (mean of 2011-13).

Table 3 Effect of mulching and fertigation on soil moisture content, physico-chemical properties and enzymatic activities in soil

Treatment	Soil moisture content * (%)					EC** (dS/m)		pH**		Bulk density** (Mg/m^3)		Dehydrogenase** (µg TPF/g/h)	Acid phosphatase** (µg PNPP/g/h)	Alkaline phosphatase **(µg PNPP /g/h)	Urease** (µg/g/h)
	Flowering	Pegging	Pod formation	Pod development	Maturity	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm				
Mulching															
M_1: No Mulch	23.8	16.0	18.2	25.5	27.1	0.55	0.55	7.49	7.51	1.25	1.22	5.79	840.7	1165.2	113.5
M_2: Polythene mulch	27.9	19.7	22.5	26.0	27.9	0.57	0.55	7.54	7.55	1.25	1.24	5.89	834.0	1185.7	115.2
LSD (P≤0.05)	2.4	1.5	1.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation															
F_1: DF with 50 % RDF	25.9	17.8	20.9	25.6	27.3	0.59	0.6	7.53	7.55	1.25	1.23	5.64	804.4	1113.7	123.1
F_2: DF with 75% RDF	26.5	17.8	21.2	27.2	27.4	0.6	0.55	7.55	7.54	1.26	1.24	6.32	873.2	1122.1	119.0
F_3: DF with 100% RDF	27.5	18.2	21.2	27.1	27.1	0.55	0.55	7.51	7.52	1.25	1.23	5.38	854.9	1282.5	112.5
F_4: DI + soil application of 100% RDF	29.2	19.7	22.9	27.5	28.2	0.54	0.53	7.49	7.52	1.25	1.23	5.76	865.8	1138.9	103.2
F_5: FI + soil application of 100% RDF	20.1	15.4	16.5	21.6	27.4	0.53	0.52	7.51	7.51	1.25	1.23	6.09	788.5	1220.1	113.8
LSD (P≤0.05)	4.8	2.0	3.7	2.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	151.0	NS

*Mean data for three years; ** After three years; DF: Drip fertigation; DI: Drip irrigation; FI: Furrow irrigation; NS: Non-significant.

Table 4 Effect of mulching and fertigation on N, P and K balances (kg/ha) in soil after peanut harvest

Treatment	Initial soil N status (A)	N added (B)*	N uptake (C)*	Expected balance in soil {(A+B)-C} (D)	Soil N status after harvest (E)	Apparent balance, gain (E-D) or loss (D-E) (F)	Actual gain (E-A) /loss (A-E) (G)	Initial soil P status (A)	P added (B)*	P uptake (C)*	Expected balance in soil {(A+B)-C} (D)	Soil P status after harvest (E)	Apparent balance, gain (E-D) or loss (D-E) (F)	Actual gain (E-A)/ loss (A-E) (G)	Initial soil K status (A)	K added (B)*	K uptake (C)*	Expected balance in soil {(A+B)-C} (D)	Soil K status after harvest (E)	Apparent balance, gain (E-D) or loss (D-E) (F)	Actual gain (E-A)/ loss (A-E) (G)
Mulching																					
M_1: No Mulch	125.4	21.3	84.4	62.3	144.2	81.8	18.8	18.6	18.7	14.9	22.4	22.6	0.3	4.0	223.1	21.2	39.0	205.3	277.8	72.5	54.7
M_2: Polythene mulch	125.4	21.3	108.9	37.8	153.2	115.4	27.8	18.6	18.7	19.0	18.3	29.0	10.7	10.4	223.1	21.2	52.9	191.4	290.9	99.4	67.8
LSD ($P \leq 0.05$)			6.9		NS					1.5		5.8					3.2		NS		
Fertigation																					
F_1: DF with 50 % RDF	125.4	12.5	83.4	54.5	135.1	80.6	9.7	18.6	11.0	14.1	15.5	21.7	6.2	3.1	223.1	12.5	35.8	199.8	269.2	69.5	46.1
F_2: DF with 75% RDF	125.4	18.8	94.4	49.8	149.3	99.5	23.9	18.6	16.5	17.3	17.8	25.6	7.8	7.0	223.1	18.7	46.2	195.6	279.7	84.1	56.6
F_3: DF with 100% RDF	125.4	25.0	101.4	49.0	153.4	104.5	28.0	18.6	22.0	17.7	22.9	27.2	4.4	8.6	223.1	24.9	48.0	200.0	284.0	84.0	60.9
F_4: DI + soil application of 100% RDF	125.4	25.0	103.6	46.8	150.9	104.1	25.5	18.6	22.0	18.8	21.8	27.9	6.1	9.3	223.1	24.9	51.6	196.4	298.7	102.4	75.6
F_5: FI + soil application of 100% RDF	125.4	25.0	100.4	50.0	154.7	104.7	29.3	18.6	22.0	17.0	23.6	26.5	2.9	7.9	223.1	24.9	47.9	200.1	290.3	90.1	67.2
LSD ($P \leq 0.05$)			8.0		10.2					1.6		5.2					3.5		17.6		

*Mean data for three years. DF: Drip fertigation; DI: Drip irrigation; FI: Furrow irrigation; NS: Non-significant.

stages over no mulch (Table 3). However, no significant difference in soil moisture was found due to polythene mulch at pod development and maturity stages owing to initiation of decomposition and withering of polythene mulch which could not prevent evaporation losses of conserved soil moisture. Ghosh *et al*. (2006) and Ramakrishna *et al*. (2006) also reported higher soil moisture with polythene mulch in peanut.

The soil application of 100% RDF under drip irrigation, being at par with 50, 75 and 100% RDF through drip fertigation, had significantly higher soil moisture content as compared to control (furrow irrigation and soil application of 100% RDF) at all the growth stages except at maturity. The application of predetermined amount of water at regular intervals in drip irrigation maintains high moisture content in the soil (Jat *et al*. 2011).

Physical and chemical properties of soil

Polythene mulching and fertigation did not show any significant effect on pH, electrical conductivity and bulk density of the soil after three years of experimentation at both soil depths (0-15 and 15-30 cm) (Table 3).

Soil enzyme activities

There was no significant influence on the activities of dehydrogenase, acid and alkaline phosphatases, and urease enzymes due to mulch treatment; however, activities of these enzymes were observed higher under polythene mulch after three years of experimentation (Table 3). Similarly, fertigation levels did not have any significant effect on the activities of dehydrogenase, acid phosphatase, and urease after three years of experimentation. However, significantly higher activity of alkaline phosphatase enzyme was recorded under drip fertigation with 100% RDF over 50 and 75% RDF, and was at par with rest of the treatments.

Nutrient uptake and soil nutrient dynamics

Use of polythene mulch significantly enhanced the nutrients (N, P and K) uptake by peanut crop to the tune of 29.0, 27.5 and 35.6%, respectively over no mulch (Table 4). It has been found that the polythene mulch prevented leaching of fertilizers as it acted as a physical barrier to rainfall. In addition, the reduced weed competition under mulch might have triggered the plant to use the available resources more effectively, and hence the NPK uptake was also observed to be more (Subrahmaniyan *et al*. 2008b). This higher uptake can be correlated with more crop yield. Significantly higher N uptake was recorded under drip irrigation and soil application of 100% RDF by 24.2 and 9.7% over 50 and 75% RDF through drip fertigation and was at par with other treatments. The P uptake increased significantly up to 75% RDF through drip fertigation by 22.7% over 50% RDF through drip fertigation and was at par with rest of the treatments. On the other hand, significantly higher K uptake was registered under soil application of 100% RDF with drip irrigation over all the other treatments. The increase in K uptake due to this treatment was 44.1, 11.7, 7.5 and 7.7% higher over 50, 75 and 100% RDF through drip fertigation, and furrow irrigation and soil application of 100% RDF, respectively.

Compared to initial status, actual available N status after cropping of three cycles improved under both no mulch and polythene mulch treatments but the magnitude of increase was more in polythene mulch treatment compared to no mulch (Table 4). The soil N status after crop harvest improved under polythene mulch by 6.2% over no mulch but the difference was not found significant. Use of polythene mulch registered lower expected N balance (37.8 kg/ha) and higher apparent N balance (115.4 kg/ha) compared to no mulch (62.3 and 81.8 kg/ha, respectively). The apparent P balance (10.7 kg/ha), actual P gain (10.4 kg/ha) and soil P status (29.0 kg P/ha) were higher under polythene mulch while expected P balance (22.4 kg/ha) was higher under no mulch due to less uptake (Table 4). Similarly, higher apparent K balance (99.4 kg/ha), actual K gain (67.8 kg/ha) and soil K status (290.9 kg/ha) were recorded under polythene mulch while expected K balance (205.3 kg/ha) was higher under no mulch due to less uptake (Table 4).

Compared to initial N status, there was improvement in actual N status under all the fertigation treatments and it ranged from 9.7 to 29.3 kg/ha (Table 4). Similarly, apparent N balance was also found positive under all the treatments and ranged from 80.6 to 104.7 kg/ha. Soil N status also improved under all the fertigation treatments and it was highest under soil application of 100% RDF and furrow irrigation. Actual P gain was higher (9.3 kg/ha) under the treatment receiving soil application of 100% RDF and drip irrigation, while apparent P balance was higher (7.8 kg P/ha) in the plots receiving 75% RDF through drip fertigation compared to other treatments (Table 4). Apparent K balance (102.4 kg/ha) and actual K gain (75.6 kg/ha) were also higher under the treatment receiving soil application of 100% RDF and drip irrigation. Soil P and K status also improved under all the fertigation treatments as compared to initial status and it was lowest under the treatment receiving 50% RDF through drip fertigation probably due to continuously less addition of P and K fertilizers.

Conclusions

On the basis of three years' experimentation, it can be concluded that the use of polythene mulch significantly improved productivity, profitability, partial factor productivity and water productivity in peanut over no mulch owing to congenial environment sustained at every growth stages and assured growth and development of peanut plants. Likewise, drip fertigation with 75% RDF significantly enhanced the productivity and profitability of peanut and was at par to drip fertigation with 100% RDF, drip irrigation and soil application of 100% RDF and, furrow irrigation and soil application of 100% RDF, thus indicating the saving of water and nutrients simultaneously. However, partial factor productivity was higher under 50% RDF through drip fertigation while water productivity was higher under drip irrigation and soil application of 100% RDF. Higher

N, P and K uptake by peanut crop was also obtained by using drip irrigation, while positive soil nutrient balances were also achieved under the present set of treatments after three cropping cycles. Soil enzymatic activities failed to show any mark variation over the treatments except alkaline phosphatase at 100% RDF through drip fertigation.

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