POD SOWING TECHNIQUE CUM PRIMING ON GROWTH, YIELD, YIELD ATTRIBUTING CHARACTERS AND ECONOMICS OF GROUNDNUT (*ARACHIS HYPOGAEA* L.)

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Abstract. Field experiments were conducted during the dry season of 2017 (June– September) and the wet season of 2017–2018 (December–March) at Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam, Cuddalore district of Tamil Nadu to study the pod sowing technique cum priming on the growth and productivity of groundnut (*Arachis hypogaea* L.). The experiment was conducted in a split-plot design (SPD) with three replications. The main plot treatments consisted of three spacing (30 × 10 cm; 30 × 15 cm and 30 × 20 cm) treatments while the four pod priming subplot treatments were as follows: Control (dry pod), 1% $CaCl_2$; 1% KH_2 PO_4 and water soaking. It can be concluded that the new and novel method of pod sowing with 30 × 15 cm combined with 1% $CaCl_2$ may be recommended. Hence from this study, it can be concluded that the novel method of pod sowing with 30 × 15 cm combined with 1% $CaCl_2$ with a higher benefit-cost ratio of 2.19 and 2.23 for spacing and pod priming respectively. Hence, it may be recommended in areas across the globe where labor shortage, drudgery reduction, vagaries in monsoon, mechanized cultivation are typical to get assured crop establishment and cultivation of groundnut for getting higher yield and profit.
Keywords: *pod, germination, crop establishment, spacing, pod treatment*

Introduction

India is heavily dependent on imports to meet its edible oil requirements and it is the largest importer of vegetable oils in the world (15% share) followed by China and USA. India is a global player in the edible oil industry, ranking as the second largest importer and the third largest consumer of edible oil. Moreover, India holds the position of the fourth largest oilseed producer (Singh et al., 2017). To meet this demand, it is essential to enhance the productivity of prominent oilseed crops of the country like groundnut through spacing, pod priming, and crop establishment strategies. The peanut plant population density has been studied extensively in many environments where this crop is grown. Recommendations for inter-row and intra-row spacings, which result in different plant populations per unit area, vary according to either kernel or pod sowing methods. The spatial arrangement of plants was also shown to be an important factor in determining the yield potential of peanuts, with the equidistant plant arrangement giving the maximum pod yield (Bell et al., 1987). In recent years, some encouraging results with pre-sowing treatment on the yield and oil content of groundnut have been reported (Ghosh and Maity, 2001). Groundnut seed with its high oil content is a good substrate for the development of pathogens. There are several seed and soil-borne diseases of groundnut which cause considerable damage to the seeds and seedlings emerging from the soil. The pods have to be shelled only a few days before sowing and in most cases in anticipation of rainfall farmers sow the seeds but scanty rainfall induces germination and crop failure happens. A fully mature pod can often be difficult to split open with the stress of the fingers is the only option that ensures good germination percentage. Normal kernel sowing limits germination as the upper layers of the soil dry out before the radical emerges and suspend germination this can be overcome by pod sowing wherein the split groundnut shells facilitate the radical for the emergence and further establishment. Wherever the hand shelling of groundnut pods is not possible due to scarcity of laborers, groundnut decorticators (both hand-operated and power operated) can be utilized for shelling the pods for seed purposes. However, the germination percentage is poor if the pods are decorticated for seed purposes. Considering the above limitations in groundnut cultivation attempts were made to investigate the new idea of pod sowing with pod priming for better crop establishment to get maximum pod yield in groundnut.

Materials and methods

Field experiments were conducted during the dry season of 2017 (June–September) and the wet season of 2017–2018 (December–March) at Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam (11° 30' N, 79° 26' E, 42.67 m altitude). The soil was a red sandy loam in texture, low in available nitrogen (N; 165 kg ha^{-1}), moderate in available phosphorus (P_2O_5; 19.5 kg ha^{-1}) and available potassium (K_2O; 154 kg ha^{-1}), with a pH of 7.3. The experiment was conducted in a split-plot design (SPD) with three replications. The main plot treatments consisted of three spacing (S_1: 30 × 10 cm; S_2: 30 × 15 cm and S_3: 30 × 20 cm) treatments while the four pod priming subplot treatments: P_1: Control (dry pod), P_2: 1% $CaCl_2$ (chosen as a priming agent due to its biological significance, stress tolerance enhancement, and regulatory role in plant growth processes); P_3: 1% KH_2 PO_4(chosen as a priming agent due to its provision of essential phosphorus and the resulting benefits for root growth, energy transfer, and stress tolerance) and P_4: Pod soaking with water. Foliar spray dose of 1% is based on a combination of factors aimed at preserving plant health, minimizing potential risks, adhering to regulatory standards, and promoting sustainable agricultural practices. Using lower concentrations helps ensure the efficacy of foliar treatments while reducing the likelihood of adverse effects on plant growth, the environment, and overall agricultural sustainability. The field was divided into three blocks (replications). In each block, three main plots were marked to accommodate the spacing treatments. Each main plot was further divided into four sub-plots to accommodate different pod priming. A uniform fertilizer schedule of 25:50:75 kg N, P_2O_5, and K_2O ha^{-1} was applied for groundnut. The entire quantity was applied at the time of sowing for groundnut pods. Pendimethalin was applied at 1.0 Lha^{-1} as a pre-emergence herbicide and it was applied in a spray volume of 500 L water for one ha using a knapsack sprayer fitted with a flat fan nozzle and one hand weeding at 20 days after sowing (DAS). The bunchy type peanut variety VRI(G)-8 pods (mostly two kernel pods and rarely

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single/three kernel pods) of 100-105 days duration were used as seed material. The pods were sown in line manually with women's laborers as per the treatment spacing. The pods were placed in the shallow rills (*Fig. 1*) made with peg markers at specified inter and intra-row spacing and covered with the same soil to a depth of 2-4 cm after seedling emergence (*Fig. 2*) one healthy plantlet was left and the remaining plantlet was thinned out to maintain the plant population as per the spacing treatments.

Figure 1. *Pod sowing of groundnut in the experimental plot*

Figure 2. *Germination of kernels from the pods*

Data collection and analysis

Crop yield Crops were harvested manually by uprooting and stripping with the help of a groundnut stripper. The biological yield, pod yield, and haulm yields were recorded.

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Economic analysis

The economic analysis in terms of gross and net returns and benefit: cost ratio (returns per rupee invested) were made out based on the existing rate of inputs and output in the local market (*Table 1*). Total variable cost included the cost of inputs such as pods, fertilizers, irrigation, and the cost for various cultural operations such as ploughing, sowing, weeding, harvesting, stripping, etc. The rental value of land was also considered in the cost of cultivation. Returns were calculated by using the following formulas:

Gross returns = Value of the kernels/seeds + Value of haulms (Eq.1)

Net returns = Gross returns–Total variable costs (Eq.2)

Benefit: Cost ratio = Gross returns/Total variable cost (Eq.3)

Table 1. *Average costs for different inputs and outputs during 2017 and 2017-18*

S. No	Particulars	Cost (₹ ha^{-1})
1	Ploughing	1000
2	Levelling	750
3	Forming bunds & channel	2400
4	Seed cost (Pods)	
	30 × 10 cm (585 kg/ha)	26325
	30 × 15 cm (390 kg/ha)	17550
	30 × 20 cm (286 kg/ha)	12870
5	Labor for pod sowing	
	30 × 10 cm (8 women labor)	2400
	30 × 15 cm (7 women labor)	2100
	30 × 20 cm (6 women labor)	1800
6	Manures and fertilizers including application cost	13180
7	Hand weeding on 20 DAS	3000
8	Pesticides including application cost	2500
9	Rent	1000
10	Irrigation including cost of labor	6000
11	Priming	
	Control (Dry pod)	0
	1% $CaCl_2$ for pod priming	350
	1% KH_2PO_4 for pod priming	500
	Pod soaking with water	300
13	Motorized stripper charges including cost of labor	
	30 × 10 cm	8000
	30 × 15 cm	7000
	30 × 20 cm	6000
14	Pod (₹ t^{-1})	40000
15	Haulm (₹ t^{-1})	1500

Statistical analysis

The data recorded for different parameters were analyzed with the help of the analysis of variance (ANOVA) technique for a split-plot design using MSTAT-C software. The results are presented at a 5% level of significance (p = 0.05). Also, the pair wise mean comparison was carried out using the Fisher LSD post hoc test, as described by Gomez and Gomez (1984).

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Results

Growth attributes

The incremental increase in the intra-row spacing for pod sowing not influenced the germination of groundnut. Similarly, the priming of groundnut pods also did not influence the germination percentage (*Table 2*). Each successive increase in intra-row pod sowing of groundnut increased and higher plant height (50.2 cm) was recorded with the wider intra-row spacing of 30 × 20 cm (*Table 2*). Contradictory to the plant height the higher LAI (6.40) and dry matter production (7.24 tha^{-1}) with closer intra-row spacing of 30 × 10 cm.

Table 2. *Effect of spacing and primed pod sowing on the growth, yield and economics of groundnut during 2017 and 2017-2018 (mean)*

Treatment	Germination (%)	Plant Height (cm)	Leaf Area Index (LAI) (90 DAS)	Dry matter production (tha^{-1})	Pods/pl ant	100 seed weight (g)	Pod yield (tha^{-1})	Haulm yield (tha^{-1})	Harvest index	Economics: Cost of cultivation ($\times 10^3$ ₹ ha^{-1})	Economics: Net returns ($\times 10^3$ ₹ ha^{-1})
Spacing											
S_1-30 × 10 cm	96.23	47.3c	6.40a	7.24a	27.24c	43.22c	3.192c	4.348c	0.423	66.84	67.36
S_2-30 × 15 cm	95.45	48.5b	5.82b	6.70b	29.52b	44.12b	2.947b	3.973b	0.426	56.77	67.52
S_3-30 × 20 cm	95.12	50.2a	5.25b	6.03c	31.69a	45.89a	2.501a	3.609a	0.409	50.79	54.97
SEm ±	1.74	0.89	0.10	0.12	0.54	0.88	0.06	0.07	0.004		
CD (P = 0.05)	NS	1.93	0.22	0.25	1.18	1.91	0.13	0.16	NS		
Pod priming											
P_1-Control (Dry pod)	94.07	47.2b	5.43b	6.05c	27.11d	44.25c	2.661d	3.589d	0.440	57.85	53.98
P_2-Pod priming @1% $CaCl_2$	96.35	51.2a	6.27a	7.19a	31.89a	45.89a	3.086a	4.104a	0.423	58.20	71.40
P_3-Pod priming @1% KH_2PO_4	95.98	48.5bc	6.15b	6.67b	29.52b	45.90a	2.945b	4.025b	0.429	58.35	65.49
P_4-Pod soaking with water	94.53	47.6c	5.90b	6.14c	28.45c	45.16b	2.785c	3.813c	0.449	58.15	58.97
SEm ±	1.72	0.89	0.11	0.12	0.53	0.84	0.05	0.07	0.007		
CD (P = 0.05)	NS	1.96	0.25	0.27	1.17	NS	0.12	0.16	NS		

Based on the prevailing market prices for inputs, machinery cum labor hiring charges, and the minimum support price for pod and haulm yields

Yield attributes, yield, and harvest index

The pods per plant were highest with 30 × 20 cm spacing (31.69) whereas 30 × 10 cm recorded the lowest (27.24) and pods sown with 30 × 15 cm produced intermediate (*Table 2*). A similar trend of results was obtained for 100 kernel weight. The management practices and microclimatic environment were mainly complimentary for producing the highest number of pods per plant with 30 × 20 cm row spacing might be due to less antagonism among the plants by competing for sufficient space and airflow for the growth and development of groundnut crops. Among the pod priming treatments,1% $CaCl_2$ recorded a higher yield (3.086 tha^{-1}), and a lesser yield (2.661 t ha⁻

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^{1}) was recorded with direct sowing of the pod without any kind of priming treatments. A similar kind of response was exhibited with the haulm yield of groundnut for spacing and pod priming treatments. The harvest index differed numerically with row spacing (*Table 2*). The harvest index increased from 0.423 to 0.426 with increasing the intra-row spacing from 10 to 20 cm and thereafter further increase in intra-row spacing decreased the harvest index to 0.409.

Economics

The highest cost of cultivation (66.84 × 10^3 ₹ ha^{-1}**)** was with 30 × 10 cm which was followed by 30 × 15 cm (56.77 × 10^3 ₹ ha^{-1}) and the lesser cost of cultivation (50.78 × 10^3 ₹ ha^{-1}) was recorded with 30 × 20 cm spacing among the treatments tested in the study. Though the cost of cultivation recorded on the higher side but promising net returns and B:C ratios (*Fig. 3*) were obtained with pod sowing spacing treatments both in 30 × 15 cm (67.52 × 10^3 ₹ ha^{-1}; 2.19) and 30 × 10 cm (67.36 × 10^3 ₹ ha^{-1}; 2.01) except the wider intra-row spacing of 30 × 20 cm (54.97 × 10^3 ₹ ha^{-1}; 2.08) respectively. At the 5% level of significance, spacing treatment using Fisher LSD revealed a significant difference, with pod sowing at 30 × 15 cm spacing showing the highest CD value (0.0151), followed by 30 × 20 cm and 30 × 10 cm (*Fig. 3*). Similarly, for pod priming treatments at the 5% level of significance, Fisher LSD analysis indicated a significant difference with the highest CD value (0.0020) observed for pod priming using 1% $CaCl_2$, followed by 1% KH_2PO_4, pod soaking with water, and the dry pod sowing method.

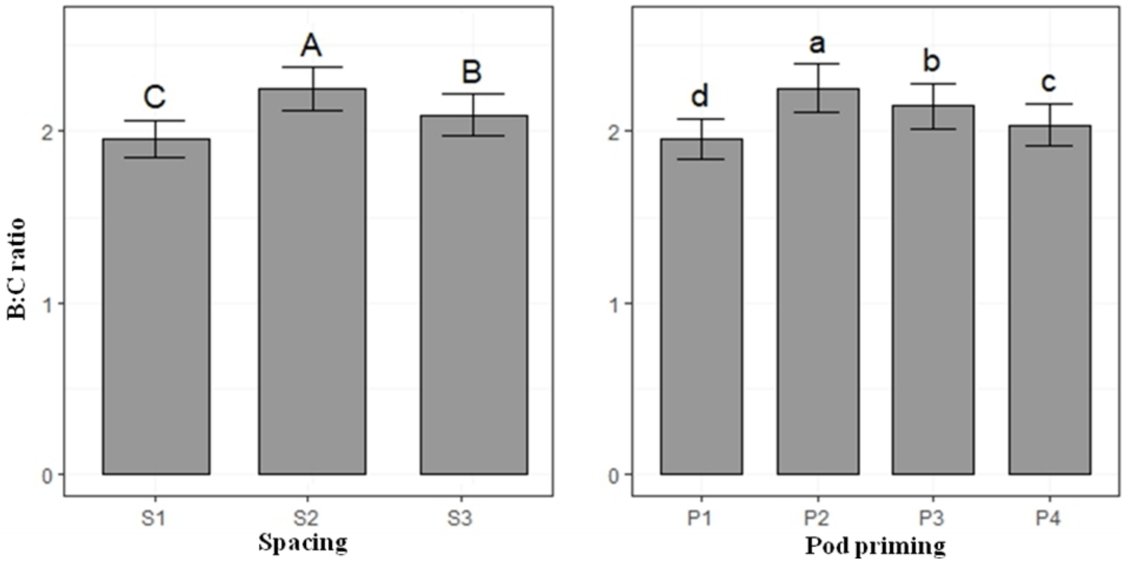

Figure 3. *Response of groundnut to spacing under varying pod priming methods of establishment (based on mean of two years)*

Though the pod priming treatments may not incur any costs for priming the yield advantage was recorded with 1% $CaCl_2$; 1% KH_2PO_4 and soaking in water were exhibited in terms of recorded net returns and B:C ratios. The highest cost of cultivation is mainly due to the higher cost incurred for seed material (pods) looks less profitable and even in kernel sowing as well. However, in the era of mechanized cultivation and

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unforeseen situations of labor shortage, drudgery reduction and to cope with vagaries in monsoon the pod sown seed material will establish with subsequent rains in the rainfed and normal garden land ecosystem.

Discussion

In a study conducted in scarce rainfall zone of *Andhra Pradesh*, various treatment combinations were investigated, including ridge and furrow with 30 × 10 cm spacing, flat bed with crop compaction and 30 × 10 cm spacing, and flat bed with crop compaction and 60 × 10 cm spacing. Among these, the treatment combination of flat bed with crop compaction and 30 × 10 cm spacing resulted in higher pod and haulm yields (Nelapati et al., 2022). A study conducted in *Sierra Leone* aimed to determine the optimum growth parameters. The researchers recommended planting Kabam1 on mounds with an inter-row spacing of 50 cm × 20 cm (Bendu et al., 2023). The same trend of increased LAI with closer spacing was reported by Awal and LijaAktar (2015). Among the pod priming treatments numerically higher germination and statistically highest plant height, LAI, and dry matter production were reported with 1% $CaCl_2$. The pre-sowing soaking for 10 h with 1% $CaCl_2$ positively influenced the germination, seedling vigor, and root-shoot ratio resulting in superior performance. The same results were in corroboration with Solaimalai and Subburamu (2004). The results were similar to the findings of Patil et al. (2007) and Awal and Lija Aktar (2015). In pod priming with 1% $CaCl_2$ treatment recorded higher pods per plant (31.89) which was followed by pod priming with 1% KH_2PO_4 and soaking with water were intermediate in the production of pods per plant and the lowest was recorded with absolute control (Dry pod sowing). Priming with $CaCl_2$ (1%) solution for 12 h is advantageous to obtain healthy seedlings in groundnut was reported by Mohammady et al. (2021). In another study by Vinothini and Bhavyashree (2019) reported that kernels primed with coconut water@ 50% registered higher germination (91%), root length (20.20 cm), shoot length (16.30 cm), dry matter production (3.68 g seedling^{-1}) than other orgopriming treatments.

In sesame seed hardening in with 2% potassium dihydrogen phosphate significantly increased growth and yield attributes and yield (Venkatakrishnan, 1998). Generally adopted spacing of 30 × 10 cm for kernel sowing was also found good for a novel method of pod sowing in getting higher pod yield (3.192 tha^{-1}) whereas the wider intra-row spacing with 30 × 20 cm spacing recorded lesser pod yield (2.501 tha^{-1}). A similar result is reported by Patra et al. (1998). Kaushik and Chaubey (2000) reported that groundnut yield improved with a reduction in row-to-row spacing. Jahan (1998) also found that an increase in population density generally tended to decrease the harvest index in green gram which is parallel to our findings for up to 20 cm increase in the intra row spacing. A similar kind of result in the case of groundnut cultivation if the organics are available at cheaper cost integration of organics may be adopted (Karunakaran et al., 2010). Further pod priming is an added advantage to cope with the biotic and abiotic stress environments safeguarding the sown seed material (pods) in the soil for growth and development.

Conclusion

Hence from this study, it can be concluded that the new and novel method of pod sowing with 30 × 15 cm combined with 1% $CaCl_2$ may be recommended in areas where

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labor shortage, drudgery reduction, vagaries in monsoon, mechanized cultivation across the globe to get assured crop establishment and cultivation of groundnut for getting higher yield profit and soil health.

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