SUITABLE CROP ESTABLISHMENT METHOD AND INTERCROPS FOR SEMI-SPREADING GROUNDNUT (*ARACHIS HYPOGAEA* L.) IN DRYLAND RAINFED ECOSYSTEM OF NORTH EASTERN ZONE OF TAMIL NADU

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(Received 11th Jan 2024; accepted 23rd Sep 2024)

Abstract. The prevalence of uneven rainfall distribution and intermittent droughts during the crop growth period frequently lead to crop failure. Semi-spreading groundnut demonstrates resilience to moisture stress under diverse land configurations, offering opportunities for intercropping. This adaptability not only helps the groundnut crop withstand challenging environmental conditions but also presents a potential strategy for mitigating risks during drought years. Under these circumstances, this study was conducted to investigate the efficacy of semi-spreading groundnut for the north eastern zone of Tamil Nadu, India. The experiment employed a strip plot layout with 12 treatment combinations *viz*., Seed drill sowing with raised beds (90 cm) of Groundnut + Black gram (M_1S_1); Groundnut + Cowpea (M_1S_2) Groundnut + Red gram (M_1S_3); Groundnut + Castor (M_1S_4); Seed drill sowing with compartmental bunding of Groundnut + Black gram (M_2S_1); Groundnut + Cowpea (M_2S_2) Groundnut + Red gram (M_2S_3); Groundnut + Castor (M_2S_4) Seed drill sowing with no land configuration of Groundnut + Black gram (M_3S_1); Groundnut + Cowpea (M_3S_2) Groundnut + Red gram (M_3S_3) Groundnut + Castor (M_3S_4). The groundnut variety TMV 10 was utilized, and collected data were subjected to statistical analysis to determine the study's outcomes. The adoption of the seed drill sowing with raised bed and compartmental bunding crop establishment technique resulted in a higher pod yield of 703 kg/ha, surpassing the flatbed method of sowing which yielded 605 kg/ha. Among the intercrops, cowpea and castor exhibited notably higher seed yields. An overall Benefit-Cost Ratio (BCR) analysis revealed that opting for compartmental bunding, raised bed with a red gram/cowpea intercrop provided the maximum return of $ 1.43 per $ invested.
Keywords: *pod yield, land configuration, soil moisture, rainfall use efficiency*

Introduction

Groundnut (*Arachis hypogaea* L.) is a globally significant food and oilseed crop known for its high protein content (Ciftci and Suna, 2022; Sathe and Seeram, 2018), valued for both human and animal nutrition. India, which adopted groundnut cultivation from the ancient days, has risen to become a leading global producer. However, India's

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_123135

groundnut production fluctuates due to factors like weather, pests, and government policies. In the 2020-2021 season, India produced approximately 9.43 million metric tons of groundnuts (source: Ministry of Agriculture & Farmers Welfare, Government of India, https://agriwelfare.gov.in/en/StatHortEst). Major groundnut-producing states include Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, and Telangana, with Gujarat being the top producer. In Tamil Nadu, groundnut plays a significant role, covering 70% of rainfed crop areas and 30% under irrigation. Notably, 43% of groundnut cultivation in Tamil Nadu is concentrated in the North Eastern Zone (Korla Harshavardhan et al., 2022).

The primary challenge in groundnut production is the lack of appropriate technology for soil and water management, particularly in regions with unpredictable rainfall. Relying on rain-dependent moisture conservation practices remains crucial for the future of groundnut agriculture in India (Rajitha et al., 2018). Effective soil moisture management is the key factor (Harisudan and Subrahmaniyan, 2020) coupled with adoption of suitable crop establishment techniques will lead to higher yields compared to traditional sowing methods.

Intercropping in groundnut offers several important advantages, including enhanced resource utilization, reduced risks from adverse environmental conditions, and improved overall farm productivity. It plays a major role in resource use efficiency, as highlighted by Li and Zhao (2015), who indicated that intercropping allows for the efficient utilization of available resources (Feng et al., 2021) such as land, water, and nutrients. Multiple crops can be grown together, ensuring that land is used to its full potential, and resources are optimally allocated. This can lead to increased overall yields per unit area. Intercropping also serves as a risk-mitigation strategy. When adverse weather conditions, such as drought or pest infestations, affect one crop, the other crop(s) may still thrive. This diversity in plant species can reduce the financial and yield risks for farmers, as demonstrated by Lithourgidis et al. (2011). Furthermore, Khan et al. (2001) found that intercropping systems can disrupt the buildup of pests and diseases, as they may have a more challenging time spreading within a diverse crop community. This can reduce the need for chemical pesticides and promote a healthier, more sustainable farming ecosystem. Hauggaard-Nielsen et al. (2008) indicated that certain intercrops, like legumes, can fix atmospheric nitrogen and improve soil fertility. This can benefit not only the intercropped groundnut but also subsequent crops in rotation. Intercropping also helps farmers diversify their income sources. Different crops may have distinct market demands and price fluctuations, reducing the financial vulnerability associated with relying on a single crop, as highlighted by Ngwira et al. (2013). Incorporating intercropping practices into groundnut cultivation can provide a range of benefits, contributing to sustainable and resilient agricultural systems.

Semi-spreading groundnut contributes to moisture conservation by covering the ground with its canopy, acting as a natural mulch that reduces the impact of direct sunlight on the soil. This helps slow down evaporation and keeps the soil surface cooler. Its robust root system binds soil particles together, mitigating the risk of erosion caused by rainfall and wind. Additionally, its vigorous growth and dense canopy suppress weeds. Integrating semi-spreading groundnut into crop rotation systems improves overall soil health, enhances moisture conservation (Anila et al., 2016; Balasubramanian et al., 2023), and contributes organic matter to the soil, increasing its water-holding capacity. It also exhibits better resilience to dry spells and efficiently utilizes available moisture due to its symbiotic relationship with nitrogen-fixing bacteria in its root nodules. This nitrogen

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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fixation enhances soil fertility and nutrient availability, indirectly benefiting moisture retention. Consequently, semi-spreading groundnut plays a pivotal role in conserving moisture by reducing evaporation, preventing soil erosion, suppressing weeds, and enhancing soil fertility (Reddy and Reddy, 2018). These characteristics make it an invaluable crop choice for rainfed and water-constrained environments, where effective moisture management is essential for successful agriculture. Semi-spreading groundnut withstands moisture stress conditions and offers scope for intercropping. Intercropping offers risk mitigation during drought years. Uneven distribution of rainfall and intermittent drought during the crop growth period leads to crop failure. Based on this rationale, an experimental trial was conducted to develop suitable crop establishment methods and intercropping practices for groundnut in rainfed conditions.

Materials and methods

The field experiment was conducted during the *Kharif* seasons of 2018, 2019, and 2020 at dryland rainfed multi locations *viz*., Oilseeds Research Station in Tindivanam, Dryland Agricultural Research Station in Chettinadu, Regional Research Station in Paiyur, and Tapioca and Castor Research Station in Yethapur (*Fig. 1*).

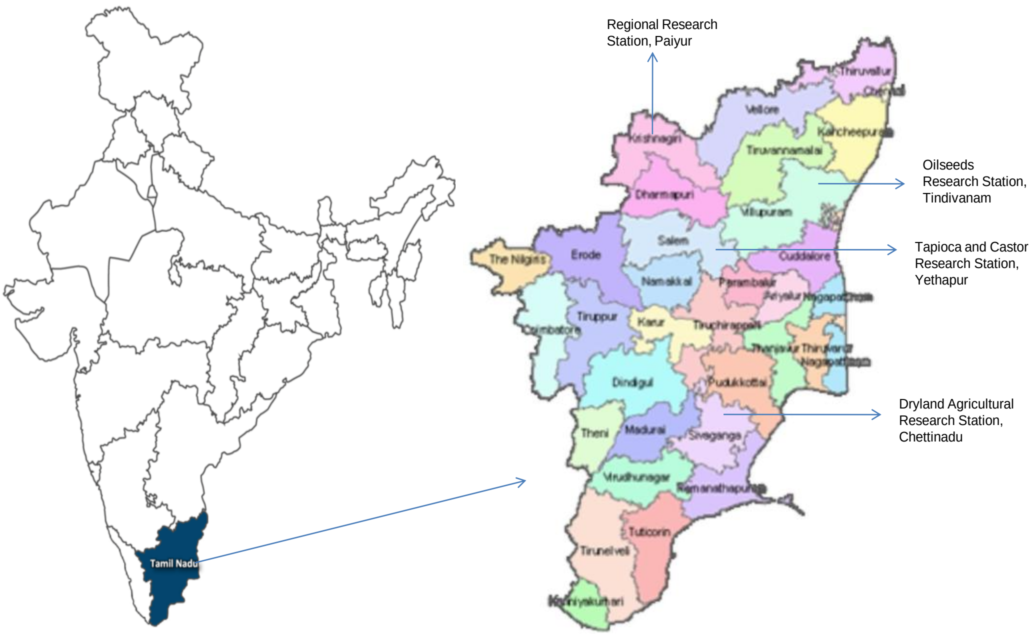

Figure 1. *The geographical location of the experimental study*

The soil details for the experiment are provided in *Table 1*. The experiment was designed using a strip plot layout, which included 12 treatment combinations. The main plot involved three land configuration practices: M_1 - Seed drill sowing with raised beds (90 cm), M_2 - Seed drill sowing with compartmental bunding and M_3 - Seed drill sowing with no land configuration. The subplot treatments included four intercrops: S_1 - Groundnut + Black gram, S_2 - Groundnut + Cowpea, S_3 - Groundnut + Red gram, and S_4 - Groundnut + Castor. The land configuration layout is depicted in *Figure 2*. The crop was sown with a spacing of 30 cm × 10 cm and seed rate of 120 kg/ha. The variety

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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used was TMV 10 and the recommended fertilizer dose was 10:10:45 NPK kg/ha. All other recommended practices were followed as per the crop's requirements (Subrahmaniyan et al., 2018).

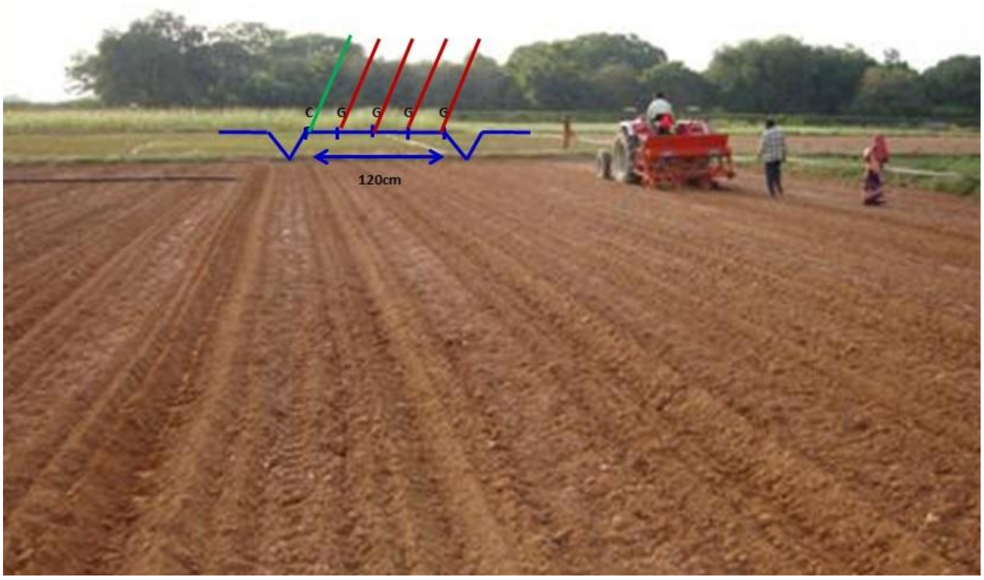

Figure 2. *Land configuration lay out*

The details of rainfall received in the experiment location are depicted in *Figure 3*. In 2018, the respective annual rainfall totals for Tindivanam, Chettinad, Paiyur, and Yethapur were 309 mm, 202 mm, 186 mm, and 183 mm. These amounts were spread over 13 days, 8 days and 7 days of rainfall, respectively. In the following year, 2019, the rainfall patterns were quite different. Tindivanam received 707 mm of rain over 38 rainy days, Chettinad had 148 mm of rainfall across 14 rainy days, Paiyur recorded 854 mm of rainfall over 32 rainy days and Yethapur received 707 mm of rain over 41 rainy days. Moving on to 2020, during the crop growth period, the rainfall distribution varied again. Tindivanam experienced 926 mm of rain across 24 rainy days, Chettinad had 147 mm of rainfall over 10 rainy days, Paiyur recorded 369 mm of rain across 16 rainy days and Yethapur received 204 mm of rain over 15 rainy days.

Figure 3. *Rainfall received during the cropping period*

Crop data collection

Five plants were randomly selected and tagged in each plot to measure various crop growth and yield characteristics, including plant height, number of pods per plant, test

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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weight, and pod yield (kg/ha) at the harvesting stage of groundnut (Harisudan et al., 2024). Additionally, the growth and yield parameters of intercrops were recorded at harvest. The groundnut pod yield was quantified as the total yield per plot, subsequently transformed into kg/ha (Harisudan et al., 2023). Soil moisture content, rainfall use efficiency, and benefit-cost ratio were evaluated at the end of the cropping period.

Soil and nutrient analysis

Prior to commencing the experiment each year, soil samples were collected and analyzed for important physicochemical properties. The results of these analyses are provided in *Table 1*.

Table 1. *Initial soil physico-chemical properties (Pooled mean of 3 years data of four centers)*

Parameters	Oilseeds Research Station, Tindivanam	Dryland Agricultural Research Station, Chettinadu	Regional Research Station, Paiyur	Tapioca and Castor Research Station, Yethapur
Soil	Red soil	Red soil	Red soil	Red soil
Soil texture	Sandy clay loam	Sandy loam	Red sandy loam	Sandy loam
pH	7	5.7	7.82	6.8
EC (d Sm^{-1})	0.8	0.02	0.18	0.4
Aval N (Kg/ha)	141	157	230	265
Aval P (Kg/ha)	28.5	26	17.6	6.7
Aval K (Kg/ha)	153.5	170	342	286

All four locations have “Red soil,” but the soil texture varies. The pH levels vary significantly among the locations. RRS, Paiyur has the highest pH (7.82), while Dryland Agricultural Research Station, Chettinadu has the lowest pH (5.7). pH levels can affect nutrient availability in the soil and influence crop selection. The electrical conductivity (EC) values also show significant differences across the locations. Oilseeds Research Station, Tindivanam has the highest EC (0.8 dsm^{-1}), while Dryland Agricultural Research Station, Chettinadu has the lowest EC (0.02 dsm^{-1}). EC reflects the soil’s salinity and can impact crop suitability and irrigation management.

Available Nutrients (N, P, K): The available nutrient levels (N, P, K) vary among locations, with Regional Research Station, Paiyur generally having higher nutrient levels compared to the other locations. This suggests differences in soil fertility, which can affect crop productivity and yield potential.

Statistical analysis

The collected data were statistically analyzed using the methods suggested by Gomez and Gomez (1984) to assess the influence of various treatments on the growth and yield attributes of Groundnut. Significant differences between treatments, when observed, will be determined at a five percent (0.05) probability level for result interpretation.

Results

Plant population

Plant population in agriculture refers to the arrangement and density of plants within a given area of cultivated land. Among the Crop Establishment Methods Seed drill

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sowing with compartmental bunding had the highest plant population of 267,265 plants/ha, followed closely by Seed drill sowing with raised beds (90 cm) of 267,181 plants/ha, while Seed drill sowing with no land configuration had a slightly lower plant population (264,777 plants/ha).

Among the intercropping combinations Groundnut + Black gram had the highest plant population (265,506 plants/ha), followed by Groundnut + Red gram with 266,504 plants/ha. Groundnut + Cowpea had a lower plant population (201,529 plants/ha), and Groundnut + Castor had 262,282 plants/ha.

In terms of standard error the differences in plant population between the Crop Establishment Methods are relatively small, while there's more significant difference between Intercropping combinations. The critical difference values indicate that, for the Intercropping combinations, Groundnut + Cowpea showed a significantly lower plant population than the others, with a CD of 0.34.

Plant height

Plant height is relatively similar across the Crop Establishment Methods, with Seed drill sowing with raised bed, Seed drill sowing with compartmental bunding and Seed drill sowing with no land configuration, having heights around 34 cm. Among the Intercropping combinations, Groundnut + Cowpea has the highest plant height (33.92 cm), followed by Groundnut + Red gram (34.23 cm). Groundnut + Black gram registered slightly lower plant height (33.52 cm), and Groundnut + Castor had a height of 34.36 cm. The critical difference values suggest that there are no significant differences in plant height among the treatments.

Number of pods per plant

Among the Crop Establishment Methods, Seed drill sowing with compartmental bunding had registered higher number of pods per plant (16.48), and less in seed drill sowing with no land configuration (15.425). Among the Intercropping combinations, Groundnut + Cowpea produced higher number of pods per plant (16.65), followed by Groundnut + Castor (16.58), Groundnut + Redgram (16.55), and Groundnut + Black gram (15.33).

Test weight

Test weight is relatively consistent among the crop establishment methods, with seed drill sowing with compartmental bunding having the highest test weight (32.38 g), and lower test weight obtained in Seed drill sowing with no land configuration (31.6 g). Among the Intercropping combinations, Groundnut + Cowpea has the highest test weight (32.30 g), followed by Groundnut + redgram (32.33 g), Groundnut + castor (32.05 g), and Groundnut + blackgram (31.25 g). Among the intercropping, Cowpea registered a higher test weight of 33.8 g and castor and red gram equally responded on test weight in all the locations.

Pod yield

Among the Crop Establishment Methods, Seed drill sowing with compartmental bunding recorded higher pod yield (703 kg/ha), followed by Seed drill sowing with raised bed (665 kg/ha), and Seed drill sowing with no land configuration (605 kg/ha).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Among the intercropping combinations, Groundnut + Cowpea registered higher pod yield (700 kg/ha), followed by Groundnut + Redgram (684 kg/ha), Groundnut + blackgram (666 kg/ha), and Groundnut + castor (650 kg/ha) (*Table 2*).

Table 2. *Effect of land configuration and intercrops on growth and yield attributes of groundnut (3 years pooled data of four centers)*

Treatments	Plant population (Nos./ha)	Plant height	No. of pods/plant	Test weight (g)	Pod yield (kg/ha)
Factor A. Crop establishment					
M_1 - Seed drill sowing with raised bed (90 cm)	267181	34.45	16.88	31.93	665
M_2 - Seed drill sowing with compartmental bunding	267265	34.23	16.48	32.38	703
M_3 - Seed drill sowing (no land configuration)	264777	33.25	15.425	31.6	605
SEd	3481	0.78	0.28	0.92	30.4
CD (P = 0.05)	10551	1.99	0.78	2.02	71.2
Factor B. Intercropping (6:1)					
S_1 - Groundnut + Black gram (VBN 4)	265506	33.52	15.33	31.25	666
S_2 - Groundnut + Cowpea (CO (CP) 7)	201529	33.92	16.65	32.30	700
S_3 - Groundnut + Red gram (VBN 3)	266504	34.23	16.55	32.33	684
S_4 - Groundnut + Castor (YRCH 1)	262282	34.36	16.58	32.05	650
SEd		0.15	0.28	1.05	26.7
CD (P = 0.05)		0.34	0.75	2.31	62.2

Intercrop yield

The yield results for different crops under various crop establishment methods indicate notable differences. For Blackgram, the highest yield (140 kg/ha) was achieved with seed drill sowing with raised bed (M_1), followed by compartmental bunding (M_2) at 133 kg/ha, and the lowest with no land configuration (M_3) at 125 kg/ha, resulting in a mean of 132.25 kg/ha and an SD of 7.75. Cowpea showed the highest yield (219 kg/ha) with seed drill sowing with raised bed, followed by compartmental bunding (193 kg/ha) and No land configuration (172 kg/ha), with a mean of 194.5 kg/ha and an SD of 25.25. Redgram’s highest yield (117 kg/ha) was also with seed drill sowing with raised bed M_1, followed by M_2 (101 kg/ha) and M3 (89 kg/ha), yielding a mean of 102 kg/ha (*Table 3*).

Soil moisture

Soil moisture is critically important in rainfed agriculture, where crops rely primarily on rainfall for their water supply. The availability and management of soil moisture play a significant role in the success and sustainability of rainfed crop production.

The experimental data on soil moisture showed (*Table 4*) that among the Crop Establishment Methods Seed drill sowing with raised bed and Seed drill sowing with compartmental bunding have relatively similar soil moisture content, both around 20.4%–20.5%. Seed drill sowing with no land configuration, which uses seed drill sowing with no land configuration, has a slightly lower soil moisture content at 18.2%.

Rainfall use efficiency

Rainfall Use Efficiency is a critical concept in crop production that helps optimize water use, adapt to changing climate conditions, and enhance agricultural sustainability. In this experiment the treatment Seed drill sowing with compartmental bunding exhibits

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the highest Rainfall Use Efficiency (2.57 Kg ha mm^{-1}) among the Crop Establishment Methods, followed closely by Seed drill sowing with raised bed (2.51 kg ha mm^{-1}). Seed drill sowing no land configuration recorded slightly lower Rainfall Use Efficiency (kg ha mm^{-1}).

Table 3. *Effect of land configuration on yield of intercrops (3 years pooled data of four centers)*

Treatments	**Yield (kg/ha)**			
Factor A. Crop establishment	**Blackgram**	**Cowpea**	**Redgram**	**Castor**
M_1 - Seed drill sowing with raised bed (90 cm)	140	219	117	169
M_2-Seed drill sowing with compartmental bunding	133	193	101	143
M_3 - Seed drill sowing (no land configuration)	125	172	89	129
Mean	132.25	194.5	102	146.5
SD	7.75	25.25	14.5	20.5

Table 4. *Effect of land configuration and intercrops on soil moisture, rainwater use and economics (3 years pooled data of four centers)*

Treatments	**Soil moisture content (%)**	**Rainfall use efficiency (kg ha mm^{-1})**	**B:C ratio**
Factor A. Crop establishment			
M_1 - Seed drill sowing with raised bed (90 cm)	20.5	2.51	1.43
M_2-Seed drill sowing with compartmental bunding	20.4	2.57	1.44
M_3 - Seed drill sowing (no land configuration)	18.2	2.21	1.32
SEd	-	0.44	-
CD (P = 0.05)	-	0.11	-
Factor B. Intercropping (6:1)			
S_1 - Groundnut + Black gram (VBN 4)	19.6	2.55	1.39
S_2 - Groundnut + Cowpea (CO (CP) 7)	20.4	2.38	1.40
S_3 - Groundnut + Red gram (VBN 3)	19.5	2.43	1.49
S_4 - Groundnut + Castor (YRCH 1)	19.2	2.38	1.44
SEd	0.18	0.64	-
CD (P = 0.05)	0.39	0.68	-

Economics

Economics helps farmers allocate their limited resources efficiently. This includes decisions about land use, labor, capital, and inputs like seeds, fertilizers, and pesticides. Economic analysis assists in determining the optimal combination of resources to maximize crop yields and profitability. The result showed that the treatment Seed drill showing with compartmental bunding has the highest B:C ratio (1.44), followed by Seed drill sowing with no land configuration has the lowest B:C ratio (1.32) among the Crop Establishment Methods.

Impact of intercrops

There are variations in soil moisture content, Rainfall Use Efficiency, and B:C ratio among the different Intercropping combinations. The choice of companion crop (Black gram, Cowpea, Red gram, or Castor) has an influence on these parameters.

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Soil fertility

The nutrient availability data provided in the table can offer insights into soil fertility for succeeding crops. Soil fertility is a crucial factor in determining the success of subsequent crops. In this experiment result indicated that, in terms of crop establishment (Factor A), the seed drill sowing methods resulted in similar levels of available nutrients (N, P, and K). Therefore, the choice of crop establishment method did not significantly impact nutrient availability. Among the intercropping treatments Groundnut + Cowpea showed the highest available N and K levels, while Groundnut + Castor had the lowest available N and K levels. The choice of intercrop significantly affected nutrient availability (*Table 5*).

Table 5. *Effect of land configuration and intercrops on soil fertility (3 years pooled data of four centers)*

Treatments	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Factor A. Crop establishment			
M_1 - Seed drill sowing with raised bed (90 cm)	182.3	18.2	188.5
M_2-Seed drill sowing with compartmental bunding	186.8	18.9	188.5
M_3 - Seed drill sowing (no land configuration)	183.5	17.95	187.0
SEd	3.15	0.32	2.61
CD (P = 0.05)	6.88	0.80	5.88
Factor B. Intercropping (6:1)			
S_1 - Groundnut + black gram (VBN 4)	185.3	18.3	187.7
S_2 - Groundnut + cowpea (CO (CP) 7)	189.8	18.1	190.0
S_3 - Groundnut + red gram (VBN 3)	186.8	17.9	190.25
S_4 - Groundnut + castor (YRCH 1)	177.75	18.38	184.75
SEd	3.23	0.29	2.49
CD (P = 0.05)	8.43	0.72	5.61

Discussion

Crop growth and yield parameters of groundnut

Plant population is a crucial aspect of crop management that can significantly impact agricultural productivity and crop health. The appropriate plant population varies depending on the specific crop being grown, local environmental conditions, and the goals of the farmer. Plant height is a fundamental indicator of a plant’s growth and development over time, providing insights into its progression from germination to maturity. Monitoring plant height is crucial for evaluating the effectiveness of various agricultural practices. Taller plants often have a competitive advantage over shorter ones in capturing sunlight, essential for photosynthesis. This phenomenon, well-documented by Weiner (1985), also extends to a greater ability to reach nutrient-rich areas in the soil (Eissenstat et al., 2000).

Among intercropping combinations, Groundnut + Cowpea had the highest plant height (34.36 cm), followed by Groundnut + Red gram (34.23 cm). Groundnut + Black gram registered slightly lower plant height (33.52 cm), and Groundnut + Castor had a height of 33.92 cm. Taller plants resulted in the production of more branches and a greater number of pods per plant (16.48), as confirmed by Khan et al. (2017) and Nweke et al. (2013). Test weight was relatively consistent across Crop Establishment

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Methods, with seed drill sowing with compartmental bunding having the highest test weight (32.38 g), while the lowest test weight was observed in seed drill sowing with no land configuration (31.6 g). The high moisture retention capacity of compartmental bunding influenced better crop growth, and its combination with cowpea produced grains with higher test weight (32.30 g) due to good compatibility, supported by Langat et al. (2006) in groundnut + sorghum intercropping. Crop establishment methods had significant influence on the yield parameters (Harisudan and Sapre, 2019).

Higher pod yield was obtained from seed drill sowing with compartmental bunding, along with cowpea intercropping, which registered a pod yield of 703 kg/ha. In contrast, Groundnut + Castor recorded the lowest yield (650 kg/ha) due to its shade effect on the main crop and competitiveness, as proven by El-Aref Kh et al. (2019). The higher yield may be attributed to the complementary effect of the leguminous crop, supplying nitrogen through better nodulation and atmospheric nitrogen fixation (Harisudan and Manivannan, 2018). The intercropped legumes its crop residues in addition to N fixation would release the nutrient at steady and balanced rate which would increase the soil fertility (Harisudan, 2019.

Intercrop yield

The yield data presented in the table highlights the significant impact of different crop establishment methods on the productivity of Blackgram, Cowpea, Redgram, and Castor. Among the three methods tested, seed drill sowing with raised bed (90 cm) consistently produced the highest yields across all crops, suggesting that this method may provide optimal conditions for growth. For instance, Blackgram and Cowpea yields were highest with the raised bed method at 140 kg/ha and 219 kg/ha, respectively. This method also resulted in the highest yields for Redgram and Castor, at 117 kg/ha and 169 kg/ha, respectively. In comparison, the compartmental bunding method yielded slightly lower results, while the no land configuration method consistently resulted in the lowest yields for all crops. These findings suggest that raised bed sowing may enhance soil aeration, moisture retention, and root development, thereby improving overall crop performance. Previous studies have also supported the benefits of raised bed planting, including improved water use efficiency and reduced soil erosion (Govaerts et al., 2007; Hobbs et al., 2008).

Soil moisture, rainfall use efficiency and economics

Among the crop establishment methods, seed drill sowing with raised bed (M_1) and compartmental bunding (M_2) showed similar soil moisture content (20.5% and 20.4%, respectively), which were significantly higher than the no land configuration method (M_3) at 18.2%. This suggests that raised bed and compartmental bunding techniques enhance soil moisture retention, which is crucial for crop growth, especially in rainfed conditions.

The rainfall use efficiency (RUE) was highest for compartmental bunding (2.57 kg ha mm^{-1}), slightly better than seed drill sowing with raised bed (2.51 kg ha mm^{-1}), and notably higher compared to no land configuration method (2.21 kg ha mm^{-1}). This indicates that compartmental bunding is particularly effective in utilizing rainfall for crop production. For intercropping combinations, Groundnut + Cowpea (S_2) and Groundnut + Castor (S_4) achieved the highest soil moisture content (20.4% and 19.2%, respectively), while Groundnut + Black gram (S_1) and Groundnut

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+ Red gram (S_3) had slightly lower values (19.6% and 19.5%, respectively). However, Groundnut + Black gram exhibited the highest RUE (2.55 kg ha mm^{-1}), suggesting that this combination efficiently converts rainfall into crop yield.

The B:C ratio a critical economic indicator, varied across treatments, with the highest ratios observed in M_2 (1.44) and S_3 (1.49), highlighting the economic benefits of these methods and combinations. The consistent high performance of compartmental bunding and specific intercropping combinations underscores their potential in enhancing both agricultural productivity and profitability under rainfed conditions. These findings are aligned with previous research that advocates for integrated soil and water management practices to optimize resource use efficiency and economic returns (Kumar et al., 2012; Sharma et al., 2014). The groundnut price as well higher groundnut pod yield was responsible factor for higher return as intercrop equivalent yield is the function of yield and price (Harisudan et al., 2021).

Conclusion

- The adoption of the compartmental bunding/raised bed crop establishment technique resulted in a higher pod yield (703 kg/ha) compared to the flatbed method of sowing (605 kg/ha)
- Among the intercrops, cowpea and castor recorded higher seed yield.
- The overall Benefit-Cost Ratio (BCR) analysis revealed that the adoption of the compartmental bunding/raised bed crop establishment technique with a cowpea intercrop provided a maximum return of Rs. 1.43 per rupee invested. This approach was found to be economically viable for rainfed farmers, especially under severe moisture stress conditions.
- Therefore, the adoption of seed drill sowing with compartmental bunding/raised bed and cowpea intercrop combination is recommended for Alfisol under rainfed conditions.

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