Advances in Agricultural Technology & Plant Sciences
ISSN: 2640-6586
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Research Article
Volume 8 Issue 1

Climate Resilient Technologies for Enhancing Groundnut Productivity Under Rainfed Conditions

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Received Date: December 12, 2024; **Published Date:** January 02, 2025

Abstract

Groundnut, as "King of Oilseeds," is one of the third largest oilseeds produced in the world and second largest in India. India is the largest cultivator of groundnut crop in the world in terms of acreage; low yields kept it in second place in terms of output. The climate resilient technologies such as varieties, sowing equipment, intercropping systems, *insitu* and *exsitu* rainwater management, weed management, nutrient management, drought management, integrated farming systems, pest management, and harvesting of groundnut were presented and discussed in this paper. Sowing with mechanized Anantha planters during June to July with improved varieties, 20mm supplemental irrigation and foliar spray 0.5% KNo3 during dry spells, soil test-based fertilizer application, intercultivation and leaf miner control with pheromone traps, and integrated farming systems increase the productivity of groundnut in rainfed areas of India.

Keywords: Groundnut; Rain Water Management; Nutrient Management; Inter Cropping Systems and Farming Systems

Introduction

Groundnut (*Arachis hypogaea* L.) is the most important oilseed-cum-food legume crop in the world. Sustainable groundnut production promotes food security and reduces malnutrition in a swelling population. Groundnut, cultivated extensively in tropical, subtropical, and warm temperate regions, has firmly established its place in global agriculture. Covering an extensive area of approximately 32.7 million hectares, groundnut production witnessed an impressive annual yield of 53.9 million tons in 2021. Notably, the leading producers of groundnut are China, followed closely by India, highlighting the crop's immense economic and nutritional significance in these regions. A range of oilseed crops viz.groundnut , rape seed and mustard, soybean, sesame, sunflower, safflower, niger, linseed and castor (non edible) are cultivated in the country. Groundnut is popular among several edible oilseed crops. The low yield levels are attributed to cultivation of the crops mostly in rainfed areas and in marginal lands with low inputs, inadequate plant stand, imbalance fertilization, inadequate plant protection measures and improper post-harvest handling. All these factors collectively contribute to low and unstable yields of groundnut in the country.

The groundnut cultivation is unique in that it is being cultivated under four different production systems/seasons, like rainy (*Kharif*), winter/post-rainy (*Rabi*), summer, and spring, fitted into different cropping patterns/sequences. Hence, the problems and constraints are multi-varied and multi-faceted according to the production system involved. However, the major production constraint of this crop has been the confinement mainly to dry or rain-dependent areas (6.0 to 6.5 million ha). Groundnut is an energy-rich C_3 crop, yielding about 50% of oil but grown under "energy starved conditions" in the dry and marginal lands. The low and fluctuating productivity is primarily because cultivation of groundnut is mostly done on marginal lands, which are lacking in irrigation and low levels of inputs for production. Therefore, there is an urgent need to improve the productivity of groundnut with the adoption of improved technologies. The climate-resilient technologies developed at Agricultural Research Station, Ananthapuramu, Andhra Pradesh, are described hereunder.

Varieties

The groundnut varities Kadiri Harithandhra, Visista, Kadiri Lepakshi, and K-6 are suitable for rainfed conditions due to their tolerance to drought, early duration, and higher pod yield. Improved varieties recorded 10 to 12% higher yields than the local varieties (Figure 1).

Figure 1: (a) Vishista (b) Kadiri-6 (c) Kadiri lepakshi

Time of Sowing

Timely sowing helps in achieving optimum utilization of seasonal rainfall, reduces the incidence of pests and diseases, and escapes terminal drought. For groundnut, July first FN is the most appropriate time for sowing whereas for redgram , castor and cluster bean June is the suitable time for sowing. August first FN is the optimum time to sow the sorghum under dryland *alfisols* of Ananthapuramu district of Andhra Pradesh [1].

The time of sowing substantially influences the pod yield of groundnut. Experiments were conducted under irrigated conditions for 3 years at fortnightly intervals throughout the year. The results revealed that pod yield of groundnut was high when sowings were taken up in June, July, November, and December. June and July months are best suited for sowing of groundnut throughout the country; sowings are the best in the Rayalaseema region of Andhra Pradesh (Figure 2).

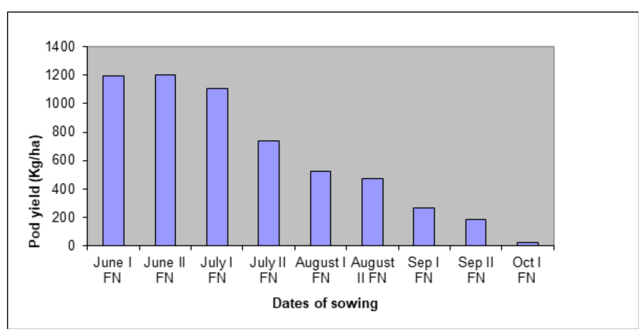

Figure 2: Groundnut pod yield vs dates of sowing.

Seed Size

Seed cost constitutes 36% of the total cost of cultivation of groundnut. Experiments were conducted with different categories of seed, viz., assort, bold, medium, small, and partially shriveled seed, with test weights of 38, 42, 28, 20, and 24 g, respectively. The results revealed that significant differences were not observed in root growth of seedlings at 10 days after sowing (DAS). Emergence percentage at 10 DAS was significantly highest in medium, small, and shriveled seed, resulting in a significantly higher seedling vigour index in shriveled and small seed than bold seed. Abnormal seedlings observed at 10 DAS were more in bold seed (34.9%) than small and shriveled seed (10.6%). Area of first and second leaves was significantly higher in bold seed than small seed. No difference was observed in the number of pegs per plant, root length, or root density per plant at harvest with different categories of seed. Pod yield and shelling percentage were not influenced by seed size (Table 1). No difference was observed in seed size distribution and emergence percentage in the progeny obtained from different sizes of seed used for sowing. Seed alone contributes from 14.6 (small seed) to 44.8 (bold seed) percent in the total cost of cultivation. Pod yield did not differ significantly by using small seed compared to bold seed in groundnut. Higher net returns and benefit cost ratios were realized with small and medium compared to bold seed. Thus, cost of cultivation was reduced by using small seed to sow groundnut crop Small and medium-sized seeds germinated better and required less weight of seeds per unit area [2] (Figures 3 & 4).

Category of seed	Pod yield (kg/ha)		Haulm yield (kg/ha)	
	2001	2002	2001	2001
Assorted	1097	626	2135	698
Bold	1180	552	2302	802
Medium	1169	568	2229	698
Small	1001	594	1801	687
Shriveled	987	626	1958	740
S.Em+	105	39	89	111
CD 5%	NS	NS	267	NS

Table 1: Effect of seed size on pod and haulm yield of groundnut.

Figure 3: Different sizes of kernel in groundnut.

Figure 4: Bold seeded kernel in groundnut (Farmers practice).

Resilient Inter Cropping Systems

The best yields of pigeon pea and castor were achieved when sown with groundnut as intercrop during June. Intercropping of groundnut + pigeonpea in 7:1or 11:1 or 15:1 row ratio instead of sole groundnut was successful. But for the sole groundnut, optimum time for sowing is June to July. If rainfall delayed beyond July month, sowing of contingent crops such as horse gram, green gram, pearl millet, cowpea, and sorghum/fodder sorghum was found profitable in the domain districts.

Among different rainfed crops, pigeonpea and castor can be grown as better alternate crops to groundnut in rainfed alfisols, as these crops gave maximum groundnut equivalent yield over years [3]. A higher groundnut equivalent yield was recorded with groundnut + pigeonpea (8:1), which was on par with the groundnut + pigeonpea (14:2) intercropping system. Higher net returns were recorded with groundnut + pigeonpea (8:1), followed by groundnut + pigeonpea (14:2), korra + pigeonpea (8:1), and korra + pigeonpea (14:2) [4].

Sowing Equipments

Tractor-drawn Ananta Groundnut + Redgram intercropping (8:1) planter: Tractor drawn Ananta groundnut planter (8 row) was developed to mechanize the groundnut sowing for timely sowing without option for intercrop sowing. This implement was modified to nine-row planter so that one middle row for intercrop of Redgram sowing simultaneously.

This nine-row planter has a middle row for Redgram and four rows on either side for groundnut, enabling 8 rows of groundnut + one row of Redgram inter cropping system (8:1). A 5 cm covering blade is also fitted behind the furrow openers to cover the furrows after seed placement [5] (Figure 5).

(a) **(b)** **(c)**

Figure 5: (a) Groundnut + Redgram (8:1) intercropping planter
(b) Traditional planter
(c) Groundnut + Redgram (8:1) intercropping

Ananta Groundnut Planter

Small and marginal farmers are unable to maintain cattle pairs due to a shortage of fodder. With the limited amount of soil moisture available for sowing, the sowing operation has to be completed within a short period of time. The seed has to be placed in the moist zone for proper germination. Tractor-drawn Anantha groundnut planter (8 rows) was developed and popularized to mechanize the groundnut sowing for timely operation with mechanical advantage. Sowing of groundnut within a short period of time and without loss of soil moisture can be done by establishing custom hiring centers (Figures 6 & 7).

Figure 6: Tractor drawn Anantha Planter.

Figure 7: Groundnut crop sown with Ananta planter.

Aqua Seed Drill

Timely sowing of crops such as castor and redgram can be done in wide-spaced dryland crops by way of pot watering at 500 ml per hill. Groundnut crop can be established with aqua seed drill. Timely sowing can be done with Aqua Planter developed by ARS, Ananthapuramu, by using 1600 to 3200 L per acre, depending on the moisture content of the soil (Figures 8 & 9).

Figure 8: Aqua planter

Figure 9: Groundnut sown with aqua planter.

Integrated Nutrient Management

Soil is the crucial medium to sustain crop productivity and resilience to drought in rainfed regions. Yet, poor soil fertility due to erosion, low SOC, emerging multinutrient deficiencies, and poor soil physical and biological environment for crop growth have become potential limiting factors for productivity enhancement in this region. Hence, improving the soil fertility, carbon storage, and soil health in the domain area with rainfed alfisols is most needed to sustain crop production.

In that context, some recommended practices for improving infiltration and water retention in soils include diverse crop rotations with legumes and addition of farmyard manure (FYM), use of groundnut shells and other crop residues, green leaf manuring, etc.

Under 37 years of long-term integrated nutrient management experiment conducted at ARS, Ananthapuramu revealed that 100% NPK and 100% NPK + ZnSO4 @ 50 kg ha^{-1} maintained higher mean pod yield (30.1 and 27.5%, respectively) than control over 37 years, but INM practice of 50% NPK + groundnut shells @ 4 t ha^{-1} sustained higher pod yield and additionally sequestered 30.2% of soil organic carbon (SOC), which is a strong determinant of soil quality and agronomic productivity, especially under arid environments. As far as soil fertility is concerned, INM practices maintained a positive balance of available N, P, K, S, Ca, Mg, Cu, Mn, Fe, Zn, and B compared to sole application of chemical fertilizers over 37 years. The addition of carbon input through groundnut shells at 4 t ha-1 is proved to be a critical practice to maintain an optimum SOC level in soil to perform its function. Thus, the integration of groundnut shells along with chemical fertilizers emerged as the practice in the domain district to sustain groundnut pod yields and soil fertility for the long term under rainfed alfisols in an arid agro-ecosystem. Besides, on-farm generation of organic matter with appropriate policy support needs to be promoted to maintain soil health and crop productivity [6].

Foliar Sprays for Drought Mitigation

The approach of foliar sprays of nutrients not only facilitates better plant growth and development but also helps to alleviate different kinds of abiotic stresses like drought. Leaf feeding is the use of foliar fertilizers to enhance the overall nutrient level in the plant and increase sugar production during times of stress. This form of foliar nutrition does not address any specific nutrient deficiency but supplies a small amount of all nutrients to keep leaf growth lush. In an experiment conducted under AICRPDA at ARS, Anathapuramu, to mitigate the mid-season drought in rainfed groundnut, the foliar spray with 0.5% KNO_3 at pod initiation and at pod development stage has increased the pod yield and mitigated the dry spells effect on pod yield.

Improving Soil Fertility in Rainfed Alfisols

The rainfed alfisols are not only thirsty but also hungry. They are poor soil nutrients as soil is subjected to fertility loss over years due to severe soil erosion. In that context, the locally practicing ITK practices, such as sheep penning, also improved the fertility. Sheep penning 1 No. per m^2 significantly increased the pod yield of groundnut by 15% and haulm yield by 32% compared to control. Sheep penning significantly increased the available K_2O in the soil and enhanced the soil fertility.

In an attempt to solubilize native soil phosphorus in rainfed groundnut, application of soil test based fertilizer (STBF) + phosphotic biofertilizer consortium (PSB @ 5 $kgha^{-1}$ + PSF @ 5 $kgha^{-1}$ + VAM @ 12.5 kg ha^{-1}) as basal dose at the time of sowing of rainfed groundnut. The results over 4 years revealed that the STBF + P biofertilizer consortium increased groundnut yield by 17.5% over control.

Rain Water Management

Rainfall is the critical input for crop production, as much of the area is devoid of irrigation facilities. Proper management of time and space variations in rainfall is the key for better crop production. Under frequent drought situations, normal crop cultivation practices are not possible. Besides, research over the years revealed that the region experiences on average five runoff events per year and leads to 4-5 tons of soil loss per hectare. Conserving the rainwater reduces the runoff and soil loss, consequently enhancing the crop yields. The following are the significant findings over years found efficient for effective rainwater management.

In-situ soil and water conservation practices increase soil water storage that helps crops to withstand moisture stress. These are simple and practiced by even individual small farmers. Suitability of the practice depends on the topography of the field. To overcome the adverse effect of sub-soil compaction in red soils and to break the hard layer, facilitating more intake of rainwater deep ploughing with a chisel plough up to 40-60 cm depth at a one-meter interval once every 2 years was found useful in groundnut, castor, and Pigeon pea (Figure 10).

These conservation furrows are formed either with a bullock-drawn traditional country plough or with a tractor-drawn conservation furrow maker in between two rows of crops across the slope to conserve the rainfall. Previous experimental results at Agricultural Research Station, Ananthapuramu, revealed that opening conservation furrows at every 3.6 m interval, i.e., for every 12 rows of groundnut crop, not only conserved moisture but also increased the pod yields by 10–14% over the years. The same technology can be advocated for other close-growing crops like pulses, millets, etc. In close-growing crops, they should be formed after crop establishment on receipt of the first rain (Figure 11).

Figure 10: Deep ploughing with subsoiler.

Figure 11: Mechanised conservation furrows in groundnut.

Farm pond of 250 m^3 capacity (size of 10 x 10 m with 2.5 m depth) with side slopes of 1.5:1 is sufficient for catchment area of 2 ha. Soil + cement lining with 6:1 ratio was found very effective in reducing seepage losses. One supplemental irrigation of 20 mm to groundnut by sprinkler during dryspells at pod development stage enhanced the pod yield by 25-30% [7] (Figure 12).

Figure 12: Farm pond lined with Soil: Cement (6:1).

Figure 12.1: Supplemental irrigation to Groundnut.

In pooled data of three years of experiment on *in-situ* moisture conservation indicated no significant differences in pod and haulm yields among all the treatments. However, higher B:C ratio was observed in micro catchments arranged after every 4 rows of groundnut and 30 cm apart in plots under mulch treatment, whereas in without mulch treatment higher pod yield was obtained in micro-catchments arranged after every six rows of groundnut with 30 cm inter catchment distance (Figures 13 & 14).

Figure 13: Micro catchments for every 4 rows.

Figure 14: Mulching on micro catchments.

Real-Time Monitoring and Management of Drought in Groundnut

Drought is the main constraint in reducing the yield of groundnut from 5 t/ha to 0.5 t/ha. Drought reduces leaf area expansion and photosynthesis, resulting in poor growth. The crop growth stages are also delayed by drought. Groundnut can tolerate drought up to 55 days in the early stages. Real-time drought management practices of subsoiling at 1 m. distance before sowing once in 2 years, formation of conservation furrows at 3.6 m. interval, spraying of KNO at 5 g/L during dryspell, and supplemental irrigation @ 20 mm at critical stages in groundnut revealed that 26 percent higher pod yield and benefit cost ratio (2.11) compared to control.

Intercropping with Mixed Pulses Technology

In Ananthapuramu district, there is a practice of growing groundnut intercropped with redgram. However, the system does not prevent the runoff losses. Improving the existing intercropping system with the innovative practice of mixing redgram with other pulses or by practicing intercropping with cowpea alone reduces the runoff to a greater extent as this acts as a vegetative barrier. Results of the experiments (1996 and 1997) revealed that intercropping of groundnut either with cowpea or mixed pulses (redgram + cowpea + horsegram) in 15 : 1 row ratio not only arrested the runoff but also increased the total returns by 17.8 and 8.5 percent, respectively, over the sole crop of groundnut. Results of the experiments under the AICAR Project (1998–2001) also revealed that intercropping of groundnut with mixed pulses reduced the runoff and soil losses, thereby conserving more soil moisture. Groundnut pod equivalents were also high with the same system as compared to sole groundnut (Figure 15).

Intercrop	Mean Runoff (%)	Pod yield (Kg/ha)		Total Returns (Rs/ha)		% Increase Over control
		1996	1997	1996	1997	
Horsegram	23.4	532	193	11156	5327	0.6
Redgram	61.2	531	210	11067	5655	3.2
Cowpea	0	615	270	12683	6425	17.8
Mixed pulses	6.3	588	272	11909	5808	8.5
Pure crop	31.3	559	243	10857	5413	---

Table 2: Impact of Different Inter Crops with Groundnut on Runoff and Crop Yields.

Figure 15: Groundnut with mixed pulses (pigeonpea+cowpea) intercropping.

Water Management

On an average, groundnut crop requires about 550-650 mm of water depending upon the soil types, season and groundnut cultivars. In general, groundnut plant is considered to be more drought tolerant than other legume crops. Among different growth stages of groundnut, maximum pod yield reduction was observed when the stress was imposed at the pod-to-kernel development stage, followed by the pod development stage (70–90 DAS) and the flowering stage (30–50 DAS) compared with no stress. Varieties ICGV-91114 and Narayani were drought resistant because of higher yield attributes, yield, and water use efficiency and they could be recommended for cultivation under arid alfisols of southern India [8]. Sankara Reddy [9] reported that flowering, peg penetration and early pod formation are the moisture sensitive period for groundnut since most of the dry matter is accumulated during these periods where as Subhash Babu, et al. [10] found pegging to pod formation stage as the most sensitive period. In Gujarat, Khatri, et al. [11] while working on a model to predict moisture availability during the crop growth period, observed that germination, vegetative development and full pegging and pod development were the critical period for moisture availability. However, many workers observed that peg initiation to pod development was the most sensitive crop stage for moisture deficit in the soil [12,13]. In a lysimeter study, Golakiya, et al. [14] reported that the growth of groundnut crop was curtailed maximum with moisture stress at flowering, but yield reduction was the maximum at pod development stage due to reduced crop reproductive efficiency. Singh, et al. [15] reported that the most sensitive crop stage for moisture stress is pod development followed by peg initiation and peak flowering. Nautiyal, et al. [16] observed that moisture stress at vegetative phase was even advantageous and imposing moisture stress about 20 days enhanced pod yield Moisture stress at vegetative stage followed by two frequent irrigation at 5 days interval creates favourable condition for early flush of synchronous flowering, more peg to pod ratio resulting in enhanced yield.

Higher pod yield with irrigation at 10 day interval than irrigating at critical growth stages was also reported from Khargone, Madhya Pradesh [17]. Four irrigations at vegetative, flowering, pegging and pod development stages in Kharif groundnut at Sriganganagar, Rajasthan gave the highest mean pod yield of 1.60 t/ha along with the maximum consumptive use of water and WUE [18]. In Punjab, providing three irrigations, each one at flowering, pegging and pod formation was considered to be the optimum for Kharif groundnut. However, if only one irrigation has to be provided, and then apply only at pod formation in the June sown crop and at peg formation in July sown crop.

Weed Management

Weed management especially under rainfed conditions is well maintained by farmers. Indigenous implements are available with farmer both in Andhra Pradesh and Gujarat. Intercultivation is generally done from 25 to 30 days after sowing and second intercultivation is being done at 40 to 45 DAS. Intercultivation followed by line weeding is generally practised. Weeding becomes a problem once in 4 to 5 years when continuous rains are received in early stages of the crop.

The interculture implement with 8 tynes has been developed with T-shape and V-shape sweeps fitted to the tynes. The size of the sweep's ranges from 4" to 6". Small size sweeps of 4" are used for first interculture at 20 to 25 days and 6" size sweeps are used for second interculture at 40 days after sowing. The tractor drawn interculture implement can run in between the row spacing of 30 cm without any damage to plants. Its field capacity is 4 to 5 ha/day. By introducing this technology in the region, the field capacity is doubled and timely weeding can be completed. Drudgery to women is reduced considerably (Figure 16).

Figure 16: Inter-cultivation with tractor drawn Ananta interculture implement.

Chemical weed control is possible under irrigated conditions. The most effective herbicides are pendimethalin @ 1 kg ai/ha, Butachlor @ 1 kg ai/ha. Preemergence application of these herbicides controls weeds effectively for 30 days.

Pest Management

The lefminer *Aproaerema modicella* is known to be a regular and serious pest infesting vast stretches of rainfed groundnut, resulting in heavy losses to the crop, and during this period, Andhra Pradesh habitually suffers from acute drought and water scarcity. Because of the concealed mode of life of these larvae and pupae under the leaf epidermis, the control of this pest continues to be a problem. Recently, the sex pheromones have been successfully employed for monitoring and also for direct control through pheromone mass trapping and mating disruption techniques.

Pheromone mass trapping techniques (PMTT) can be used efficiently for leaf miner management in groundnut in the farmer's fields. The delta sticky traps were installed at 20 per ha within 10–15 days of the emergence of the groundnut crop. Significant differences were recorded in the incidence of leaf miners in terms of damage in the fields of pheromone mass trapping and farmers practice methods. The farmers of PMMT operating villages saved an amount of Rs. 942/ha compared to farmers method and had a higher yield of 148 kg/ha with net returns of Rs. 597/ha than farmers method (Figures 17 & 18).

Figure 17: Groundnut leaf miner incidence.

Figure 18: Pheromone mediated mass trapping.

Harvesting

Harvesting is done when 75% of pods are mature. The duration of most of the groundnut varieties is from 95 to 120 days. Delay in maturity occurs with severe drought. The duration of the TMV-2 variety is 105 days, but the crop was harvested from 90 to 145 days depending on the distribution of rainfall. If rains are received around 90 to 95 days, farmers pull the plants, even if it is 10 days early since pulling of plants becomes difficult if soil dries. Spraying of fungicides for the control of late leaf spots helps in harvesting at the correct time, and even if it is delayed for a week to ten days, there will be no yield loss [19].

Integrated Farming Systems

Sheep fed with available dry fodder such as groundnut haulms and horsegram *bhusa* for 5 months recorded higher body weight and were profitable for sheep rearing after harvest of rainfed groundnut. The integrated farming system provides the additional and regular income and meets the nutritional demands of the family. The research at the on-farm research also indicates that ram lamb rearing farmers benefited by getting additional income of Rs. 300 to 400 per sheep per month after harvest of groundnut in Ananthapuramu district. By investing Rs. 3000 per ram lamb and rearing for about five months, a net profit of Rs. 1500 to 2000 could be realized. Similarly, improved poultry birds like *vanaraja, gramapriya, and rajasri* birds can be reared in small numbers (10-20). By investing an amount of Rs. 3500 per unit of desi birds (10 females + 1 male), an amount of Rs. 11500 per year as a net profit could bse realized compared to Rs. 6,000 per year by rearing *vanaraja, gramapriya, and rajasri* birds. So, rainfed groundnut and sheep rearing is a profitable farming system compared to groundnut crop alone for the scarce rainfall zone of Andhra Pradesh (Figure 19).

(a) (b)

Figure 19: (a) Stall feeding with green fodder (b) Stall feeding with dry fodder.

Conclusion

The climate resilient technologies sowing with mechanized Anantha planters during June to July with improved varieties , 20mm supplemental irrigation and foliar spray 0.5% KNo_3 during dry spells, integrated nutrient management , intercultivation and leaf miner control with pheromone traps, and integrated farming systems increase the productivity of groundnut in rainfed areas of India.

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