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Rabi groundnut (*Arachis hypogaea*) yield in different agro-ecologies of eastern India: Factors analyses

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ABSTRACT

Improving edible oilseed production is a need of the hour to ensure food security in India. Numerous efforts were made to fasten these efforts, including implementation of Cluster Frontline Demonstration (CFLDs). In this initiative, the groundnut crop has also been promoted in various parts of India in the form of CFLD under different agro-ecological zones of eastern India through the lead taken up by Krishi Vigyan Kendra, the Farm Science Centre (KVK) of Odisha and West Bengal. The assessment aimed at underlying the relative importance of the factors affecting the groundnut (*Arachis hypogaea* L.) yield in this region. A study was carried out in the winter (*rabi)* season 2018–22, revealed that the application of improved technologies, namely seed treatment, use of biofertilizers, Integrated Nutrient Management (INM), Integrated Pest Management (IPM), irrigation etc. increased groundnut yield to the tune of 46.83%. The benefit-cost ratio of demonstrated plot was much higher (2.04) against the traditional practices (1.63). Further, seed treatment, application of bio-fertilizer, and Integrated Nutrient Management (INM) were the major determinants behind enhancement of groundnut yield. These critical factors can significantly contribute towards augmenting the yield of groundnut followed by enhancing the profitability of farmers, besides addressing the agroecological challenges in different agro-ecological zones of eastern India.

Keywords: Agro-ecological zones, CFLD, Groundnut, INM, Seed treatment, Yield

Groundnut (*Arachis hypogaea* L.) is a tropical, self-pollinated, leguminous annual high-value oilseed crop. The inclusion of a leguminous crop in cropping system not only addresses several agro-ecological challenges, but also ensures food security dimensions as well as several environmental, economic and health benefits (Balazs *et al.* 2021). It has been cultivated in more than 100 countries all over the world with a total of 53.9 million tonnes production covering an area of 32.7 million ha with a productivity of 1648 kg/ha in 2017 (FAOSTAT 2021). Globally, around 90% of total groundnut is grown as a major oilseed and food crop in the semi-arid tropical region (Gangurde *et al.* 2019). Groundnut occupies 4.8 million ha area in India along with an annual production of 9.8 million tonnes and productivity of 2041 kg/ha during 2019–20 (Directorate of Oilseeds Development 2020). Depending upon the climate, soil type, land classification, and length of growing period India is divided into 20 agro-ecological zones to determine crop suitability, land use optimization, and crop diversification and to facilitate research (Gupta and Mishra 2019). The diverse climatic condition enables year-round cultivation of groundnut in *kharif*, *rabi* and summer seasons in different agro-ecological zones of this country (Kadiyala *et al.* 2021). But groundnut productivity is much higher in *rabi* season (on an average 3000 kg/ha) compared to that of *kharif* and summer season (average 821 kg/ha) (Jain *et al.* 2021) as the climatic conditions are more favourable for pathogen and weed infestation during monsoon. To avoid yield loss, adopting scientific management practices, like seed treatment, biofertilizer application, INM, weed control, integrated pest management (IPM) etc. can be beneficial.

In response to alterations in the population, income level and climate over time, several new crop technologies were introduced to the farming community by the research institutions, such as the Indian Council of Agricultural Research (ICAR). To address the importance of oilseed production, the Ministry of Agriculture and Farmers Welfare, Govt. of India had initiated nationwide Cluster Frontline Demonstration (CFLD) programme on oilseeds under National Mission on Oilseed and Oilpalm (NMOOP) during 2015–16 and National Food Security Mission:

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Oilseeds (NFSM-Oilseeds) during 2018–19. From 2015–16 to 2020–21, India's oilseed production increased by more than 43% (Chakraborty 2022). The present programme is aimed at identifying the critical parameters responsible for low yield of groundnut like inappropriate nutrient application, absence of seed treatment practices, injudicious application of plant protection chemicals and others. The main objective of CFLDs is to conduct applied research with newly released crop production technologies, varietal diversification, and capacity building through several productive interfaces (Kalita *et al.* 2019). However, the actual success of this CFLD programme depends on the extent of adoption of the demonstrated package of practices by the farmers. There exists several yield gaps (e.g. technology gap, extension gap, technology index etc.) in such technology dissemination programmes (Sah *et al.* 2021). From agricultural scientists and policymakers to extension personnel and farming community all are facing a common challenge of enhancing and sustaining groundnut productivity coupled with bridging the yield gaps as well as transferring the appropriate technologies generated by the research institutions (Choudhary and Suri 2014). Inadequate capital, lack of access to the improved cultivar, inadequate technical know-how, lack of interest and access to mechanization were found as major challenges in the adoption of improved technologies by the farmers (Agyeman *et al.* 2021). Further, it is also important to understand the relative importance of the factors affecting crop yield so that farmers who are unable to adopt all the recommended practices can be advised to take care of these most important factors affecting crop yield.

In this backdrop, the study was conducted in selected villages of Odisha and West Bengal based on work undertaken in CFLD-Oilseed programme in *rabi* season to assess the relative importance of different factors affecting the yield of groundnut in different agro-ecological zones of eastern India. The results will help not only the farmers to identify major constraints in production of *rabi* groundnut but also the KVKs to adopt better extension policy under CFLD for increasing groundnut production. Additionally, the research institutes will be able to develop a more appropriate package of practices depending on the adoption criteria as well as the feedback received from extension system.

MATERIALS AND METHODS

Study area: The current study was carried out under rainfed condition during winter (*rabi)* season for 4-consecutive years (2018–19, 2019–20, 2020–21and 2021–22) in total 10 KVKs of Odisha located in the agro-ecological zones of Eastern Plateau (Chhotanagpur) and Eastern Ghats, hot sub-humid eco-region and Eastern Coastal Plain, hot sub-humid to semi-arid eco-region (covering Gajapati, Rayagada, Angul, Nabrangpur, Balasore, Bargarh, Dhenkanal, Mayurbhanj, Nuapada, Sonepur districts), respectively. Similarly, 7 KVKs of West Bengal located in the agro-ecological zone of Assam and Bengal Plain, hot sub-humid to humid eco-region covering Coochbehar, Uttar Dinajpur, Malda, Murshidabad, Hooghly, Howrah and Bankura districts were also selected according to the agro-ecological condition. The climate of the study area was mostly hot and humid and the majority of annual precipitation was received during monsoon.

Sampling of area and farmers: During last 4-years demonstration was laid down involving 1234 farmers around 493 ha of area. The farmers were mainly resource-poor having 1–2 ha of land followed by poultry and goatery at a small scale. Generally, cereal-cereal mono-cropping was dominant in these regions and the farmers conventionally opted rice crop in pre-*kharif*, *kharif* and *rabi* season. The number of farmers selected was 50 in 2018–19, 580 in 2019–20, 504 in 2020–21 and 100 in 2021–22 for conducting CFLDs on groundnut crop in West Bengal and Odisha. Therefore, a total of 1234 beneficiary farmers were selected during 2018–2022 as the samples for present investigation. The farmers were contacted both individually and in group by the KVKs. Before laying down the actual demonstration, they were trained, and exposed to improved cultivation practices of groundnut by other research organisations and the large farmers. Once the desired willingness was observed, the farmers were selected for the demonstration keeping into consideration the other stipulations earmarked in the guidelines of CFLD programme.

To ensure crop diversification, KVKs had conducted the CFLDs on groundnut crop under rainfed condition during *rabi* season for four consecutive years (2018–19, 2019–20, 2020–21 and 2021–22). The control plot represented the farmers' traditional cultivation practices (Table 1). For demonstration plots the KVK scientists had provided critical inputs such as seed, IPM, INM and bio-fertilizers to the farmers. Detailed comparison between technological interventions and existing farmers' practices under CFLD programme is given in Table1. Dharani (TCGS 1043), a drought tolerant (withstands drought up to 35 days dry spell) high yielding (potential yield is 16–26 q/ha in *kharif* and 37–43 q/ha in *rabi*) variety of groundnut having a duration of 100–105 days, released in the year of 2012 through SVRC (State Variety Release Committee), was used in this experiment. The study was conducted in experimental designs (Control-Treatment and Before-After) of social research.

Data collection and analysis: A survey was conducted in face-to-face mode with the farmers to collect information. The yield data of demonstration plots as well as control plots were collected immediately after harvesting to assess the impact of CFLD intervention on the yield of groundnut crop (2018–22). Every year pen-paper based face-to-face personal interview was conducted with the beneficiary farmers for primary data collection.

Measurement of variables: The data output was collected from both CFLD plots as well as control plots (farmers' practices) and finally increase in yield and benefit-cost ratio were computed using following formula:

$$\text{Yield increase (\%)} = \frac{D_y - F_y}{F_y} \times 100$$

Table 1 Comparison between technological interventions and existing farmers practice under cluster frontline demonstration programme

Particulars	Technological interventions	Existing farmers practice
Variety	Dharani	Indigenous variety
Seed rate	100 kg/ha	135 kg/ha
Seed treatment	Carbendazim 12% + Mancozeb 63% WP @2 g/kg or with *Trichoderma viride* @4 g/kg of seeds before sowing	No seed treatment
Bio-fertilizer application	*Rhizobium* @30 g/kg of seed	No bio-fertilizers applied
Sowing time	Mid November	Mid November
Sowing method	Line sowing (30 cm ×10 cm)	Broadcasting
Nutrient management	Soil test based application of fertilizer with the RDF of 25:40:20:45 kg NPKS/ha and micronutrients [Zn as $ZnSO_4$ (12% Zn) @5 ml/litre at pod development stage and B 20% @1 kg/ha at pre-flowering stage and @1 g/litre at pod development stage].	Blanket nutrient application with high doses of NPK
Irrigation	1 at 26–45 DAS (flowering stage), 2–3 at 46–65 DAS (pegging stage) and 2–3 at 66–105 DAS (pod development stage)	Not taken in account of critical stage
Thinning	1 at 15–20 DAS	No thinning operations
Weed control	Hand weeding, 20 and 40 DAS, Pendimethalin at 1–2 DAS @1.5 kg/ha or Imazethapyr 10% at 15–20 DAS	No weedicide has been applied
Plant protection	Neem oil @3 ml/litre, *T. viride* @5 g/litre, Ridomil gold @2.5 g/litre, Chlorothalonil @2 g/litre, EB @0.4 g/litre, Ulala @0.3 g/litre, YST @20 nos./ha, PT @5 nos./ha or Spraying of Carbendazim + Mancozeb @1 kg/ha against root rot at seedling stage, Spraying of Thiomethoxam @160 g/ha against aphids at flowering to peg formation stage, Spraying of Profenophos @1 litre/ha against Bihari caterpillar at pod formation stage.	Indiscriminate use of pesticides like Dimethoate, Imidacloprid, and Chloropyrifos

WP, Wettable powder; RDF, Recommended doses of fertilizer; DAS, Days after sowing.

Benefit-cost ratio (B:C) = Gross profit/Cost

where D_y, Yield from demonstrated plot; F_y, Farmers' practice yield.

Methods of data analyses: Artificial Neural Networks (ANNs) are mathematical models with a highly interconnected structure inspired by the structure of the human brain and nervous systems. ANN processes operate in parallel, which differentiate them from conventional computational methods. An ANN consists of a number of neurons that are arranged in an input layer, an output layer and one or more hidden layers. The input neurons receive and process the input signals and send the output to other neurons in the network where this process is continued. This process is carried out in a forward manner; hence, the term multilayer feed-forward model is used (Das *et al.* 2022). In a feed forward network, the weighted connections feed activations in the forward direction only from an input layer to output layer. Training of a neural network to perform particular function is done by adjusting the values of connections (weights) between elements. Multilinear Regression (MLR) analysis and neural network modelling were carried out using Microsoft Excel 2016, SPSS ver. 23.0 (SPSS, Inc.).

RESULTS AND DISCUSSION

Assessment of *in-vitro* performance of CFLD programme on groundnut

Groundnut yield: The study revealed that the yield of groundnut using variety Dharani with an improved package of practices shifted progressively over the years (Fig. 1). Under the demonstrated plots, the performance of groundnut (yield) was comparatively higher than the

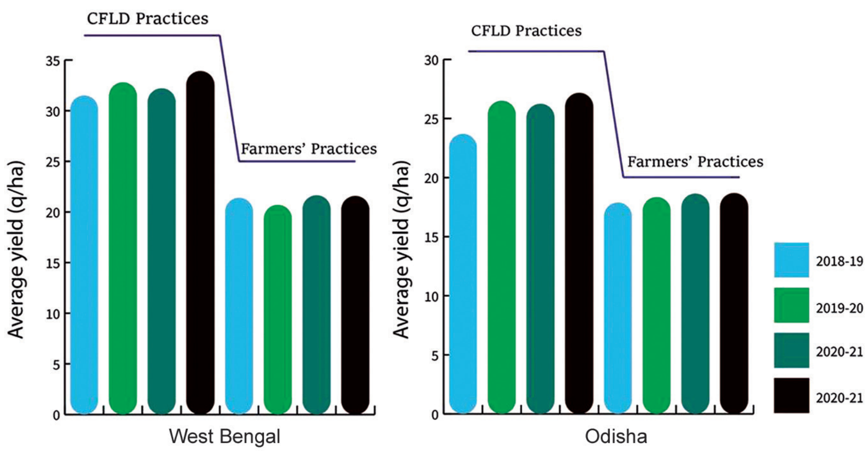

Fig. 1 Comparison of groundnut yield under CFLD practices and farmers' practice from 2018–19 to 2021–22 in West Bengal and Odisha.

Table 2 Yield comparison of groundnut under CFLD practices and farmer's practice from 2018–19 to 2021–22 in Assam and Bengal Plain, Eastern Plateau and Eastern Ghats and Eastern Coastal Plain

Agro-ecological zones of India (State)	Year	Area (ha)	No. of CFLD	CFLD variety	Potential yield of CFLD variety (q/ha)	Average CFLD yield (q/ha)	Average farmers' practice yield (q/ha)	Percent increase in yield
Assam and Bengal Plain, hot subhumid to humid eco-region (West Bengal)	2018–19	15	50	TCGS-1043 (Dharani)	43	31.50	21.40	47.20
	2019–20	110	458			32.80	20.70	58.45
	2020–21	60	217			32.20	21.64	48.80
	2021–22	35	94			33.90	21.57	57.16
Eastern Plateau (Chhotanagpur) and Eastern Ghats, hot Sub-humid eco-region and Eastern Coastal Plain, hot subhumid to semiarid eco-region (Odisha)	2018–19	15	48			23.70	17.89	32.48
	2019–20	100	222			26.50	18.35	44.41
	2020–21	110	287			26.24	18.64	40.77
	2021–22	40	100			27.16	18.68	45.40

local check. In 2019–20, the highest average yield i.e. 33.9 q/ha was recorded in Assam and Bengal Plain (West Bengal) whereas in Eastern Plateau and Eastern Ghats and Eastern Coastal Plain (Odisha) the highest average yield was 27.16 q/ha (Table 2).

The maximum yield increase percentage (58.45%) was observed in Assam and Bengal Plain in the year 2019–20. In Eastern Plateau and Eastern Ghats and Eastern Coastal Plain maximum yield was recorded (45.40%) in the year 2021–22. In the year 2020-–2021, yield was observed to increase to a lesser extent as compared to other years, both in the case of Eastern Plateau and Eastern Ghats and Eastern Coastal Plain (40.77%) and Assam and Bengal Plain (48.80%) (Table 2). The cause might be attributed to the outspread of covid-19 pandemic and related mobility restrictions.

The yield differences between the demonstration plot and control plot could be ascribed to differences in soil fertility, microclimate, varietal compatibility and adoption of technological practices (Singh *et al.* 2019, Dash *et al.* 2021). Implementation of newly released technologies with high-yielding varieties may minimize the current yield gap. Identification of site-specific problems and application of new interventions can enhance the productivity of groundnut. In a study conducted on CFLD of groundnut, Pawar *et al.* (2018) found that higher pod yield of groundnut was obtained in demonstration plot (22.03 q/ha to 29.25 q/ha) compared to farmers' practice (18.50 q/ha to 21.45 q/ha). In another study, Dash *et al.* (2021) reported 32.9% increase in the average yield of groundnut with demonstration practices compared to farmers' practices.

Benefit-cost ratio: The increasing trend of B:C ratio over the years has been found in the case of CFLD groundnut. The average gross and net monetary returns were ₹99817/ha and ₹47535/ha and for control ₹69842/ha and ₹30049/ha, respectively. B:C ratio for demonstration and control was 2.04 and 1.63, respectively (Table 3).

Over the years an increasing trend in B:C ratio was observed in the case of demonstration plot of CFLD groundnut compared to control plot due to the increased

Table 3 Economic analysis of CFLD of groundnut

Agro-ecological zones of India (State)	Year	Gross exp. (₹/ha)		Gross return (₹/ha)		Net return (₹/ha)		BCR	
		CFLD	FP	CFLD	FP	CFLD	FP	CFLD	FP
Assam and Bengal Plain, hot subhumid to humid eco-region (West Bengal)	2018–19	24300	16200	42750	23600	18450	7400	1.76	1.46
	2019–20	42392	38432	88003	63733	45913	25106	2.1	1.61
	2020–21	52092	45758	121361	115800	94803	46627	2.44	1.72
	2021–22	49115.6	45600	128450	94920	79334	49320	2.61	2.08
Eastern Plateau (Chhotanagpur) and Eastern Ghats, hot Sub-humid eco-region and Eastern Coastal Plain, hot subhumid to semiarid eco-region (Odisha)	2018–19	41330	39248	62700	52200	21310	13140	1.51	1.33
	2019–20	36310	35329	64135	43520	27812	8191	1.76	1.23
	2020–21	46862	43317	172409	77169	51658	33852	2.16	1.82
	2021–22	56250	51775	118727	87796	40996	56752	2.04	1.79
Total/Mean		43581.5	39457.4	99816.9	69842.3	47534.5	30048.5	2.0475	1.63

CFLD, Cluster frontline demonstration; FP, Farmer's practice.

yield in groundnut. Adoption of scientific management practices during groundnut cultivation in the demonstration plot was in turn, responsible for the said increment in yield. In a study conducted on rapeseed and mustard in Bihar and Jharkhand, Kumar *et al.* (2022) reported the B:C ratio of 3.85 and 2.80 respectively.

Assessment of the relative importance of the factors affecting groundnut production during rabi *season*: In the current study, the factors affecting groundnut production were taken as input and yield of groundnut was considered as output of the model. Multilayer perceptron (MLP) network was constructed with various numbers of layers and neurons in each layer, to predict the groundnut yield and the best model was selected for the one having the least error and best predictability. The best-fitted ANN model has been provided in Fig. 2.

The predictive ability of the emerged ANN models was assessed by executing sensitivity analysis. The robustness of the model was envisioned through partitioning training and testing datasets (7:3 ratio) and was trained by withdrawing one input at a time while other factors were unchanged. Inspecting the normalized importance, results revealed that seed treatment, application of bio-fertilizer, and INM were the major determinants of alterations in the groundnut yield, although some other factors also influenced the yield (Fig. 3).

To substantiate and validate this finding, stepwise Multiple Linear Regression (MLR) modelling was executed to determine the most important factors influencing groundnut yield. Taking groundnut yield as the independent variable, the relationship with other factors as dependent variables were worked out. In the current study adoption of MLR model through stepwise regression (Table 4) revealed a number of factors of which again seed treatment, application of bio-fertilizer, INM and IPM were found to be the major determinants of alterations in the yield of groundnut which corroborates the ANN findings.

Multilinear regression study and multilayer perceptron neural network analysis revealed that among several factors considering seed treatment, application of biofertilizer and INM could be the major determinants in yield enhancement. The finding is noteworthy considering the fact that yield of groundnut is affected by seed treatment earlier as well.

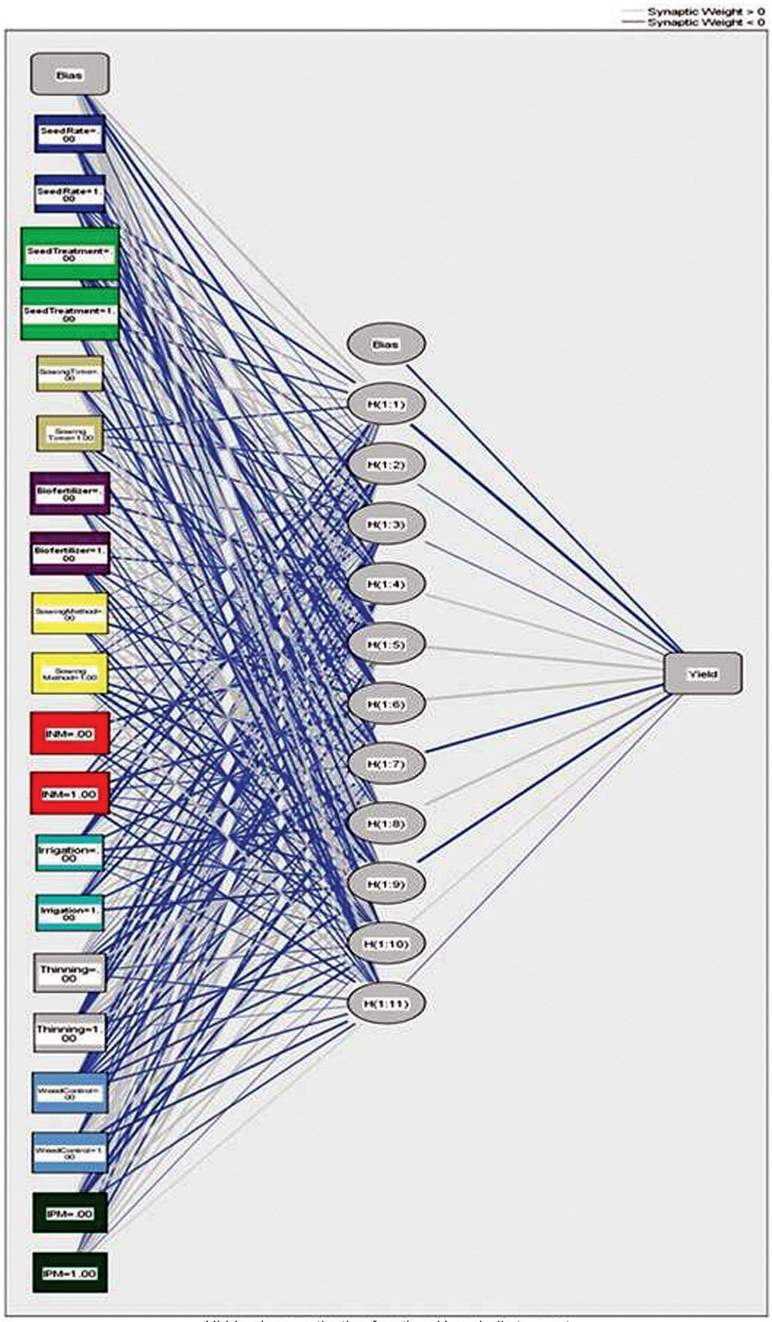

Fig. 2 Multilayer perceptron (MLP) neural network to predict groundnut yield.

Table 4 Multiple Linear Regression (MLR) modelling of yield with other factors (n=36)

MLR equation	R^2	Adj-R^2	$SE_{est.}$
Y=17.60+6.20ST** +2.36SM*+2.53INM*+2.58BF*+1.26IPM*+1.37SR-1.71TH+1.48WC+0.55SWT	0.775	0.772	2.35
Y=24.17+ 6.84ST**	0.471	0.471	3.58
*P = 0.05, **P = 0 .01			

Y, Yield; ST, Seed treatment; SM, Sowing method; INM, Integrated nutrient management; BF, Biofertilizer; IPM, Integrated pest management; SR, Seed rate; TH, Thinning; WC, Weed control; SWT, Sowing time.

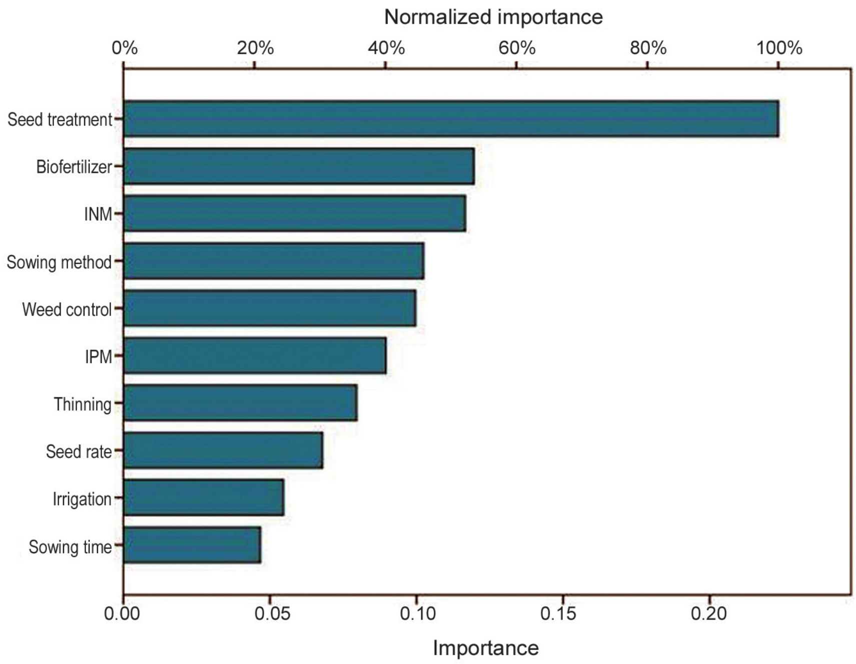

Fig. 3 Sensitivity analysis of ANN models.

Soil-borne diseases e.g., crown rot/collar rot/seedling blight (*Aspergillus niger*), Sclerotium wilt/stem rot (*Sclerotium rolfsii*), ear rot (*Aspergillus flavus*), dry wilt/dry root rot (*Macrophomina phaseolina*) are potential threat to groundnut cultivation (Hagan *et al.* 2010). Seed treatment with a suitable fungicide and bio-control agents can protect the seedlings during a vulnerable stage of their development (Walters *et al.* 2013). In the current study, groundnut seeds were treated with carbendazim 12% + mancozeb 63% WP @2 g/kg or, with *Trichoderma viride* @4 g/kg of seeds before sowing. The farmers who had not adopted seed treatment before sowing were affected by yield loss.

Being a leguminous crop groundnut has a good response towards nitrogen-fixing bacteria like *Rhizobium*, *Bradyrhizobium*, *Azotobacter* etc. As nitrogen plays a significant role in improving groundnut productivity, seed inoculation of biofertilizers like *Rhizobium*, *Bradyrhizobium* or, *Azotobacter* and plant growth promoting rhizobacteria (PGPR) ultimately results in quality and quantity produce and also makes the soil fertile for the succeeding crop (El-Sherbeny *et al.* 2023).

Adoption of INM practices with judicious and timely application of fertilizers are very important aspects of crop production. Indiscriminate use of chemical fertilizers has a deleterious effect on soil health thereby declining crop productivity (Das *et al.* 2020, Das *et al.* 2021a, Das *et al.* 2021b). Soil test-based fertilizer application is of great importance as it helps the crop to combat nutrient deficiency or, toxicity (Bekele *et al.* 2022). Vala *et al.* (2017) reported that application of 75% RDF along with 25% N through FYM and biofertilizer (*Rhizobium* and PSM) had resulted in higher yield in summer groundnut. Despite having the ability of symbiotic N fixation with *Rhizobium*, groundnut needs a large amount of N for its growth (Hou *et al.* 2014). Hence, combined application of inorganic nutrients (NPK), FYM and bio-fertilizer can be fruitful owing to their synergistic effect. Good response of groundnut towards INM may be attributed to two factors, viz. instant source of essential nutrients supplied through inorganic nutrients and synchronised release of essential nutrients throughout the crop growth period (Jain *et al.* 2017).

Conclusion and policy implications

It is inferred from the above findings of CFLDs on groundnut cv. *Dharani* that improved technology, timely operations and scientific monitoring had contributed towards increasing the yield besides tackling various agro-ecological challenges. Further, seed treatment, application of biofertilizer, and INM were the major determinants of alterations in the groundnut yield. Hence, the resource-poor farmers who are unable to adopt all the recommended practices in CFLD for increasing groundnut yield may take care of these three most important factors to alleviate major yield loss. Demonstrations under CFLD programmes have proved to be beneficial for improving yield; this will also help in horizontal expansion of improved technologies in the farmer's fields. The results of this study offer policy makers and extension agencies a new tool to reduce the yield gap and increase the production of oilseeds in comparable agro-ecological zones. Also, study indicated that improving the access to agricultural technologies can help equitable benefits to the small-holder farmers. The improved groundnut cultivation practices could really play instrumental role in enhancing yield and profitability of the farmers. The adjoining farmers witnessed various stages of crop cultivation *vis-a-vis* application of selected technologies are bound to take home positive mind-set to try the same practices in their own field. However, for its largescale dissemination, extension agencies must be involved for greater expansion of area under groundnut. Policy for raising sustainability funds to support the regular practice of seed treatment, application of bio fertilizer, and INM will ensure the long-term sustainability and scaling out of groundnut cultivation in this zone.

Ethical statement

The farmers were explained aim of study and probable outcomes including this publication; and were asked to provide their consent for sharing information for this study. Farmers consented to participate in this study and shared their information anonymously, except the disclosure of geographical and secondary information. Authors respected these ethical concerns while completing this study.

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