Groundnut (Arachis hypogaea L.) Response to Nitrogen Fertilizer and Earthing Up Practices in the Tigray Region of Ethiopia

ABSTRACT

To increase groundnut yields, integrated agronomic techniques must be implemented.The current study focuses on using starter nitrogen fertilizer in conjunction with earthing up for groundnut cultivation. Three replications and a factorial combination were used in the complete randomized block design of the experiment. Two types of earthing up (no earthing up and earthing up) and four levels of nitrogen fertilizer (0, 15, 30, and 45 kg ha^{-1}) were used in the treatment combinations.For each of the Hamedo 1 and Hamedo 2 experimental sites, two disturbed composite soil samples were collected at a depth of 20 cm before sowing. According to the data analysis, groundnut flowering and maturity were not significantly impacted by the use of nitrogen fertilizer alone or by the combined application of both fertilizer and earthing up. Groundnut plant height, number of branches per plant, number of pods per plant, number of seeds per plant, seed weight per plant, and haulm yields were not significantly affected by earthing up alone or by the co-application of nitrogen fertilizer and earthing up. Conversely, the exclusive use of nitrogen fertilizer significantly affected groundnut plant height, the number of branches per plant, the number of pods per plant, the number of seeds per plant, seed weight per plant, and haulm yield.Applying 45 kg ha^{-1} of nitrogen fertilizer to the Hamedo 1 and Hamedo 2 trial sites enhanced the haulm yield by 70.53% and 78.76%, respectively, compared to the unfertilized plots.The application of nitrogen fertilizer, either alone or in combination with earthing up, had a significant effect on groundnut pod and kernel yields. In comparison to plots that received a combined application of 45 kg ha^{-1} of nitrogen fertilizer and earthing up, the Hamedo 1 and Hamedo 2 trial sites exhibited increases in pod yields of 57.73% and 55.97%, respectively, when earthing up was combined with 15 kg ha^{-1} of nitrogen fertilizer.In the same way, applying 15 kg ha^{-1} of nitrogen fertilizer to the earthing-up soil in the Hamedo 1 and Hamedo 2 experimental sites boosted the kernel yields by 70.05% and 75.43%, respectively, in comparison to soil earthing-up plots that received 45 kg ha^{-1} nitrogen.The findings of the economic and agronomic analyses showed that applying nitrogen fertilizer and earthing up together greatly increases groundnut yields and revenues. Therefore, to increase groundnut production and receive more financial advantages, producers should consider the combined application of 15 kg ha^{-1} of nitrogen fertilizer and earthing-up.

Keywords: *Earthing-up, Groundnut, Starter nitrogen fertilizer*

1. INTRODUCTION

Groundnut (Arachis hypogaea L.) is an important third source of protein and fourth source of oil in the tropics and subtropics [1, 2]. Globally, groundnut yield was estimated to be an average of

1.70 t ha^{-1}; in Africa, however, average yields are significantly lower, at 1.1 t ha^{-1} [3]. Ethiopia's average yield was 1.70 t ha^{-1}, quite comparable to the global average yield [4]. In the Tigray region, where the specific study was conducted, groundnut is predominantly grown in warm lowland soils with sandy and sandy loam textures [5,6].Such soils are ideal because they have loose, friable characteristics that allow for easier root and peg penetration, better water infiltration, and easier harvesting of pods.Under research farming in the Tigray region, groundnut yields reached about 2.66 t ha^{-1} [6], which is significantly higher compared to the national production [4].Low groundnut production at the national level is attributed to farmers' poor agronomic management practices.

Optimum groundnut yield is achieved when the soil has optimum nutrients [6].More importantly, nitrogen (N) fertilizer is a widely required nutrient for growing all crops, due to its important role in the biochemical and physiological processes of the plant [7-9].If the soil intended for groundnut planting has less than 15.5 kg N ha^{-1}, it can be supplemented with starter N for improved groundnut yield and quality [6].Because legume crops can produce their own N through biological N fixation from the atmosphere, they rely less on synthetic N fertilizers during early growth [10,11].Hence, a starter N fertilizer of 15 to 30 kg ha^{-1} is adequate for optimal yield and protein production [6, 12].

Apart from fertilizer application, another important agronomic practice to improve groundnut yield is earthing up [13,14,15].Earthing up is the process of bringing soil around the base of the plant to cover the roots [15, 16].The practice of soil earthing up creates a favorable environment for groundnut pegs to easily penetrate the soil, protects pods from sun exposure, hinders weed growth, allows water to seep into the soil, and promotes good air movement in the soil, thereby increasing groundnut productivity.Research reports suggest that earthing up the soil for groundnut crops five weeks after sowing [15] and seven weeks after sowing [16] can boost groundnut yields.

Farmers in the Mereb Leke district, where this specific research was conducted, are interested in cultivating groundnut crops due to high protein content, which serves as a valuable food source and aids in soil fertility restoration [6]. By rotating groundnut crops with other crops, farmers can also enhance soil fertility while utilizing groundnut as a means to break pest and disease cycles [6]. However, due to a lack of information about the importance of N fertilizer in groundnut production, farmers grow groundnut without using N fertilizer. No research has been conducted on the significance of soil earthingup practices in enhancing groundnut productivity. Therefore, the objective of this study was to evaluate the contribution of soil earthing up in combination with N fertilizer in enhancing groundnut productivity.

2. MATERIALS AND METHODS

2.1. Site Description

The trial was carried outat Medhin *Tabia*in two experimental sites (Hamedo 1 and Hamedo 2), Merebleke district, Tigray, Ethiopia underirrigationin season of 2019/2020 (Figure 1). The altitude of the study areais with an altitude of 1390 meters above sea level. Mixed farming typically involving the crop and livestock production is commonly practiced on the same land unit. The area is generally known with dominant crops of sorghum, finger millet, groundnut and tef that are growing in a rotation system. Additionally, Vegetables and fruits are regularly produced in the irrigation farming. The study area is characterized by a warm semi-arid agroclimatic zone having a well-drained sandy loam and loam textures with a typical soil type of luvisols. The pattern of rainfall is unimodal with the main rainy season concentrated within the months of June to September. The annual rainfall was 636 mm, and the average monthly temperature was 25.3°C [17].

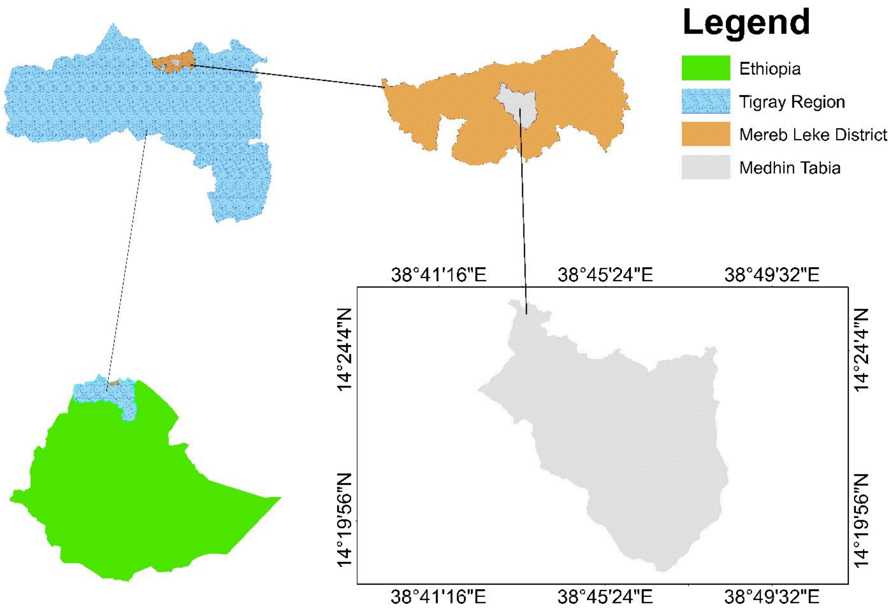

Figure 1. Study area ('tabia' is the smallest administration unit).

2.2. Experimental Design, Treatments Set up and Management

The experiment was conducted on selected two farmers' field. The field experiments were consisting of a total of 8 treatments with having two levels of earthing up i.e. no earthing up coded as NEU and earthing up coded as EU and four levels of N (0, 15, 30, and 45 kg ha^{-1}). The treatments were arranged in a 2×4 factorial combinations and laid out in randomized complete block design (RCBD) with three replications. The treatmentwith each no earthing up and zero level of N fertilizer was designated as a control treatment. Soil earthing up practice was done at 30days after sowing and before flowering and 70 days after sowingwhen flowering was stopped. Full rate of N fertilizer was applied at planting from urea source. A landrace '*Sedi*'variety was planted at a seed rate of 80 kg ha^{-1}. Size of plot used was 3.6 m×4 m (14.4 m^2) with 9.6 m^2 net harvestable plot area, and the spacing between blocks, plots, rows and plants for groundnut crop was set at 1.5 m, 1 m, 0.6 m and 0.1 m, respectively. In one plot groundnut crop, there were 5 rows and a total of 150 groundnut plants population. Harvesting was done by excluding of one border row from each side of the plot. Agronomic management practices rather than treatments differences were uniformly applied to all experimental plots per the recommendation of the area. Considering the recommended farmers' irrigation practice, all plots received a uniform irrigation water.

2.3. Soil Sampling and Analyzed Parameters

Two disturbed composite soil samples, ranging in depth from 0 to 20 cm, were gathered for each of the two locations before planting. These samples were permitted to pass through a 0.5 mm sieve for the measurement of organic carbon and total nitrogen and a 2 mm sieve for general analysis after being air-dried and milled. Two undisturbed soil samples were also collected using core sampler for estimating soil bulk density. Texture, pH, electrical conductivity (EC), organic carbon (OC), total nitrogen (TN), available phosphorus (Av. P), cation exchangeable capacity (CEC), exchangeable potassium (Exc. K), exchangeable sodium (Exc. Na), exchangeable calcium (Exc. Ca), and exchangeable magnesium (Exc. Mg) were all measured on the collected samples. After oxidizing soil organic carbon, the Bouyoucos hydrometer method was used to measure the texture of the soil [18]. Using a pH meter, the pH level of the soil was determined in the supernatant suspension of a 1:2.5 soil-to-water ratio [19]. An electrical conductivity meter was used to test the electrical conductivity of the soil in the saturated extract of a 1:2.5 soil-to-water ratio [20]. The Walkley-Black chromic acid wet oxidation method was employed to determine the value of organic carbon [21]. The Kjeldahl approach was applied to estimate the TN of the soil (22). Available P was estimated using the Olsen method [23]. Using an ammonium acetate solution for leaching, the soil's exchangeable base and cation exchange capacity were determined [24]. Table 1 provides a summary of the physical and chemical characteristics of soil.

Table 1. Soil physiochemical properties at the study sites before planting.

Soil properties	Experimental sites			
	Hamedo 1	Hamedo 2	Ratings	References
%Clay	8	11	NA	
%Silt	39	39	NA	
%Sand	53	50	NA	
Textural class	Sandy loam	Loam	NA	
Bulk density (g cm^{-3})	1.44	1.41	Moderate	[25]
pH	5.62	5.71	Moderately acid	[25]
ECe (dS m^{-1})	3.02	2.98	Slightly saline	[25]
SOC (%)	0.63	0.66	Low	[25]
TN (%)	0.04	0.05	Very low	[25]
Av. P (ppm)	7.02	7.23	Low	[25]
Exc. K (cmol (+) kg^{-1})	0.25	0.23	Low	[25]
Exc. Na (cmol (+) kg^{-1})	0.18	0.17	Low	[25]
Exc. Ca (cmol (+) kg^{-1})	6.34	9.45	Moderate	[25]
Exc. Mg (cmol (+) kg^{-1})	7.41	7.05	High	[25]

CEC (cmol (+) kg^{-1})	15.33	18.37	Moderate	[25]

2.4. Agronomic Data Collected

2.4.1. Phenological Traits

Days to 50% flowering were measured from the days after planting when 50% of the groundnut plant in each experimental plot produced flowers. Days to 90% physiological maturity were measured from the days after planting when 90% of the groundnut plant in each planting plot turned their leaves color to yellow.

2.4.2. Vegetative Traits

A graduated tape meter was used to measure ten groundnut plant heights (cm) from the base of the plant to the top of the shoot once the plant achieved maturity. In order to analyze the plant height data, the mean of the 10 plant samples was then calculated. The average number of branches per plant for each plot was determined by dividing the total number of plant branches counted from the samples by the 10 sampled plants chosen for each plot.

2.4.3. Yield and Yield Components

After harvesting groundnut plants, ten sample plants from each plot had their pod counted and totaled. The total number of pods was then divided by ten plant samples to get the number of pods per plant. Following the removal of the husks from the pods, a count of all the seeds in the 10 plant samples was made. The average number of seeds per plant was then calculated by dividing the total number of seeds counted in the 10 plant samples by the total number of plant samples. Following the weighing of the seed weight of each of the ten plant samples chosen for each plot, the weight of the ten plant samples was added up, and the seed weight per plant was calculated by dividing the total seed weight by the ten plant samples. During harvesting stage, the above ground total fresh weight of groundnut biomass was measured from a 9.6 m2 area of the experimental plot. A 200 g fresh weight sub-sample was taken from the fresh groundnut stover biomass, weighed, and oven-dried at $65^{O}C$ for 72 hours to attain constant weight. The sub-samples were reweighed to ascertain the dry weight after they had dried in the oven. Using formula 1, the stover yield was computed from the obtained sub-sample fresh weight and dry weight values.

Haulm yield = $\frac{Total\ haulm\ feresh\ weight\ (g) * Sub{-}sample\ dry\ haulm\ weight\ (g) * 10}{Sub{-}sample\ haulm\ fresh\ weight\ (g) * net\ harea\ harvested\ (9.6\ \mathrm{m2})}$, Formula 1

At harvesting, all mature pods from the plants uprooted from a 9.6 m^2 area were removed from the haulms, weighed and recorded. This was total pod fresh weight. A sub-sample of 200 g fresh pod weight was taken from the total quantity of the pods and then oven dried at 65°C for 72 hours and was used to estimatestable weight of pod and grain yieldsand adjusted to 10% moisture content and adjusted last measured weight of pod yield and grain yield was determinedat Formula 2 and Formula 4, respectively.

Pod yield = $\frac{Total\ pod\ feresh\ weight\ (g) * Sub{-}sample\ dry\ pod\ weight\ (g) * 10}{Sub{-}sample\ pod\ fresh\ weight\ (g) * Net\ harea\ harvested\ (9.6\ \mathrm{m2})}$, Formula 2

Shelling percentage as a yield component was calculated per experimental plot. The oven dried pod sub samples taken from the entire harvest of each experimental plots was weighed (pod dry weight) and then shelled. The shelled grain was weighed and then shelling percentage was estimated (Formula 2).

Shelling percentage = $\frac{Weight\ of\ shelled\ groundnut * 100}{Weigh\ of\ unshelled\ groundnut}$, Formula 3

From the measured shelling percentage, grain yield was estimated basing on the formula 4.

Grain yield = $\frac{\text{Shelling percentage} * Pod\ yield}{100}$, Formula 4

2.5. Partial Budget Analysis

To assess how beneficial earthing up and fertilizer application were, a partial budget analysis following a procedure of CIMMYT [26] was used. Accordingly, price N fertilizer, N transport cost, N application and labor cost for earthing up were considered as total variable cost, whereas land preparation, weeding, harvesting and irrigation practice remained the same between the treatment. Before calculating gross revenue, groundnut kernel yield obtained from each experimental plot, were adjusted down by 10% to reflect farmers’ practices.To estimate the prices ofgroundnut kernel yield, farm gate price was considered. Gross benefit was estimated by multiplying the farm gate price that farmers receive for the kernel yield of groundnut when they sell it. Net benefit was calculated by subtracting the total costs from the gross benefits. The marginal rate of return (%) was calculated by dividing the change in net benefit by the change in cost and multiplied by 100.

2.6.Data Analysis

Finally, the collected agronomic data were subjected to statistical analysis of a two-way analysis of variance (ANOVA). Before data analysis, normality and homogeneity the data were checked across separately levels and combination of earthing up and N fertilizer treatments.Analysis of variance was performed using SAS software version 9.1.Means were separated using Fisher's protected least significance difference (LSD) test at 95% level of probability.Pearson's correlation coefficient was used to decide the relationshipbetween the various plant phenology, growth, yield and yield component of groundnut.

3. RESULTS AND DISCUSSION

3.1. Phenological Attributes

Results signposted that each separate types of earthing up and separate individual levels of N fertilizer or combination of both agronomic managements have not brought significant effect on phenological traits of groundnut namely time of flowering and maturity (Table 2). This is attributed to the innate that groundnut could be produced satisfactory N through biological N fixation for commencing of flowering and maturation[6]. Instead of management practices, phenological parameters are more influenced by genetic and adaptation plant species to environmental stresses [27, 28]. There is a minimal growth prerequisite for plants to geminate, bloom, and mature within their normal timeframes [29].

Table 2. Effect of earthing up and N fertilizer on 50% flowering and 90% maturity of groundnut.

Earthing up	N (kg ha^{-1})	Days to flowering (50%)		Days to maturity (90%)	
		Hamedo site 1	Hamedo site 2	Hamedo site 1	Hamedo site 2
NEU	0	58.00	58.33	111.67	109.00
NEU	15	58.67	60.00	109.67	113.00
NEU	30	59.00	60.33	109.67	114.00
NEU	45	58.00	61.67	110.00	111.33
EU	0	56.00	59.33	113.33	108.67
EU	15	56.67	58.33	108.67	110.00
EU	30	59.00	59.33	112.67	110.67
EU	45	58.33	61.67	113.33	111.67
CV (%)		2.51	3.56	2.41	3.62
P value		0.37	0.72	0.51	0.81
LSD		NS	NS	NS	NS
Earthing up					
NEU		58.41	60.08	110.25	111.83
EU		57.50	59.67	112.00	110.25
CV (%)		2.51	3.56	2.41	3.62

P value	0.14	0.64	0.13	0.35
LSD	NS	NS	NS	NS
N (kg ha^{-1})				
0	57.00	58.83	112.50	108.83
15	57.67	59.17	109.17	111.50
30	59.00	59.83	111.17	112.33
45	58.17	61.67	111.67	111.50
CV (%)	2.51	3.56	2.41	3.62
P value	0.15	0.14	0.21	0.48
LSD	NS	NS	NS	NS

3.2. Growth Attributes

3.2.1. Plant Height

For the sites of Hamedo1 and Hamedo2, plant height was significantly affected by sole N fertilizer, and there were no significant differences in plant height under individual separate use of earthing up and integrated application of earthing up and N fertilizer rates (Table 3). At the highest level of N (45 kg ha^{-1}), plant height increased by 29.11% for Hamedo 1 and 22.88% for Hamedo 2 compared to plant height from the unfertilized plot. For both sites, a consistent increment trend of groundnut plant height was counted from a consistent increment of N fertilizer. The correlation study showed a significant association between haulm yield and plant height and branch count. This demonstrated that as one parameter increased, the other one followed the trend, and vice versa (Table 7). The increase in plant height was attributed to more available nutrient sources for a prolonged time from the higher nitrogen rate. N fertilizer is the most important plant nutrient in increasing vegetative growth as it enhances cell division and elongation[30]. Vegetative growth usually increases when fertilizer is applied regularly enough [31]. In line with the current result, plant height was improved after applying increased rate of N fertilizer [6].Plant health is indicated by height and growth rate, and N fertilizer is considered crucial for vegetative growth [32].

3.2.2. Number of Branches per Plant.

At both sites of Hamedo1 and Hamedo 2, number of branches per plant was significantly affected by sole N fertilizer, but not in the case of separate using of earthing up and integrated application of earthing up and N fertilizer rates (Table 3).At Hamedo1 and Hamedo2 sites, number of branches per plant were increased by 37.01% and 31.02%, respectively, when plots fertilized with45 kg N ha^{-1} relative to no fertilized plots. Number of branches per plant increased with N doses up to 45 kg ha^{-1} in both sites. Since N fertilizer promotes cell division and elongation, it is the most crucial nutrient for plants to boost vegetative growth [30]. Vegetative growth usually increases when fertilizer is supplied adequately [31]. Similar to the current findings, the number of branches per plant increased after applying a higher rate of N fertilizer [6].

Table 3. Plant height and number of branches per plant in relation to earthing up and N fertilizer.

Earthing up	N (kg ha^{-1})	Plant height (cm)		Number of branches per plant	
		Hamedo 1	Hamedo 2	Hamedo 1	Hamedo 2
NEU	0	27.40	31.60	11.73	11.67
NEU	15	30.80	36.00	12.53	13.67
NEU	30	33.93	37.07	15.67	15.00
NEU	45	35.73	39.10	16.27	15.33
EU	0	28.27	32.40	11.67	12.00
EU	15	32.67	36.47	13.40	13.67
EU	30	34.00	37.00	15.60	15.67
EU	45	36.13	39.53	15.80	15.67
CV (%)		4.43	5.38	11.16	12.55
P value		0.72	0.98	0.90	0.99
LSD		NS	NS	NS	NS
Earthing up					
NEU		31.97	35.94	14.05	13.92
EU		32.77	36.35	14.12	14.25
CV (%)		4.43	5.38	11.16	12.55
P value		0.19	0.61	0.92	0.65
LSD		NS	NS	NS	NS
N (kg ha^{-1})					
0		27.83^{D}	32.00^{C}	11.70^{B}	11.83^{B}
15		31.73^{C}	36.23^{B}	12.97^{B}	13.67^{AB}
30		33.97^{B}	37.03^{AB}	15.63^{A}	15.33^{A}
45		35.93^{A}	39.32^{A}	16.03^{A}	15.50^{A}
CV (%)		4.43	5.38	11.16	12.55
P value		< .0001	< .0001	0.0004	0.008
LSD		1.75	2.38	1.92	2.16

3.3. Yield and Yield Components

3.3.1. Number of Pods per Plant

At bothstudyareas of Hamedo 1 and Hamedo 2, using of soil earthing up alone or with combination with N fertilizer rates didn't show significant difference in pod number, but significancy was occurred at sole application of N fertilizer rates (Table 4).Plots of the planting sites of Hamedo1 and Hamedo2 have resulted in producing better number of pods per plant after fertilized with 15 kg N ha^{-1}, but decreasing trend was shown as the rates increased beyond.At Hamedo1 and Hamed2, the average large number of pods of 29.97 and 31.47 were obtained from 15 kg N ha , but it was insignificant when compared to the number of pods obtained from 30 kg N ha^{-1}. For each site, the minimum number of podswere achieved without N fertilizer application.Similar to the present findings, Getachew Gebrehana and AbebleDagnaw [33] stated that application of starter N fertilizer at the rate of 18 kg ha^{-1} resulted in higher number of pods per plant.

3.3.2. Number of Seeds per Plant

At Hamedo 1 and Hamedo 2study sites. application of N fertilizer alone affected number of seedsper plant whereas earthing up alone and in combination with N fertilizer did not bring significant changes in seed numbers (Table 4).The highest number of seed per plant was obtained from the application of 15 kg ha^{-1} N fertilizer but no significantly different seed numbers was obtained from the plots receiving 30 kg ha^{-1} N fertilizer. The low number of seeds obtained at both study sites was from plots receiving 45 kg ha^{-1}N fertilizer and unfertilized plots. Compared to unfertilized plot, 15 kg N ha^{-1}resulted in 16.48% and12.92% higher yield in Hamedo 1 and Hamedo 2, respectively. Therefore, from the present results, 15 kg ha^{-1}N played a crucial role in improving healthy seeds. The higher seed numbers at the plots receiving 15 kg ha^{-1}N fertilizer is due to the fact that legume crops use15 kg ha^{-1} N fertilizer as a starter to produce their own N. According to the research work of Tekuluet al.[6], they obtained better groundnut yields using 15 kg ha^{-1}N fertilizer.

3.3.3. Weight of Seeds per Plant

In Hamedo 1 and Hamedo 2study sites, application of N fertilizer alone affected weight of seeds per plant, but earthing up alone and in combination with N fertilizer did not cause any significant change in seed weight (Table 5). Accordingly, 15 kg N ha^{-1} produces better seed weights compared to plots received 45 kg N ha^{-1} and plots without fertilizer. However, there was no significant difference in seed weight between the plots receiving 15 kg N ha^{-1} and 30 kg N ha^{-1}.This might be due to groundnut crop fertilized with 15 kg N ha^{-1}or 30 kg N ha^{-1}had better seed filling than the plots received 45 kg N ha^{-1} and unfertilized plots. It is known that most legume crops require N fertilizer in the early stages of growth until they produce their own N from the atmosphere. Except for the earlylegume growth, the main source of their food is the N they have produced from the atmosphere through their nodules. All the yield components such as number of pods per plant, number of seeds per plant and weight of seeds per plant improved at the same rate of 15 kg N ha^{-1}. According to the correlation result, there is a significant association between the number of pods per plant, the number of seeds per plant, the weight of seeds per plant, and the yields of pods and kernels. This demonstrated that as one parameter got higher, the other one followed the trend, and vice versa (Table 7).

Table 4. Number of pods per plant and number of seeds per plant underearthing up and N fertilizer.

Earthing up	N (kg ha^{-1})	Number of pods per plant		Number of seeds per plant	
		Hamedo 1	Hamedo 2	Hamedo 1	Hamedo 2
NEU	0	24.40	27.47	61.00	68.67
NEU	15	28.87	30.93	72.17	77.33
NEU	30	28.33	30.53	70.83	76.33
NEU	45	26.27	25.13	65.67	62.83
EU	0	27.07	28.27	67.67	70.67
EU	15	31.07	32.00	77.67	80.00
EU	30	29.30	30.80	73.25	77.00
EU	45	26.80	27.30	67.00	68.25
CV (%)		7.00	8.37	7.00	8.37
P value		0.75	0.92	0.75	0.92
LSD		NS	NS	NS	NS
Earthing up					
NEU		26.97	28.52	67.42	71.29
EU		28.56	29.59	71.40	73.98
CV (%)		7	8.37	7.00	8.37
P value		0.06	0.29	0.06	0.29
LSD		NS	NS	NS	NS
N (kg ha^{-1})					
0		25.73^{C}	27.87^{BC}	64.33^{C}	69.67^{BC}
15		29.97^{A}	31.47^{A}	74.90^{A}	78.67^{A}
30		28.82^{AB}	30.67^{AB}	72.04^{AB}	76.67^{AB}
45		26.53^{BC}	26.22^{C}	66.33^{BC}	65.54^{C}
CV (%)		7.00	8.37	7.00	8.37
P value		0.0056	0.0059	0.0056	0.0059
LSD		2.38	2.98	5.95	7.44

Table 5. Response of weight of seeds per plant and haulm yield to earthing up and N fertilizer.

Earthing up	N (kg ha^{-1})	Weight of seeds per plant (gram)		Haulm yield (t ha^{-1})	
		Hamedo 1	Hamedo 2	Hamedo 1	Hamedo 2
NEU	0	18.91	21.29	4.25	4.15
NEU	15	22.37	23.97	4.98	5.08

NEU	30	21.96	23.67	6.77	6.48
NEU	45	20.36	19.48	7.15	7.33
EU	0	20.98	21.91	4.36	4.23
EU	15	24.08	24.80	4.77	5.19
EU	30	22.71	23.87	6.55	5.80
EU	45	20.77	21.16	7.54	7.65
CV (%)		7.00	8.36	13.55	19.50
P value		0.75	0.92	0.89	0.87
LSD		NS	NS	NS	NS
Earthing up					
NEU		20.90	22.10	5.79	5.76
EUA		22.13	22.94	5.81	5.72
CV (%)		7.00	8.36	13.55	19.50
P value		0.06	0.29	0.95	0.92
LSD		NS	NS	NS	NS
N (kg ha^{-1})					
0		19.95^{C}	21.60^{BC}	4.31^{B}	4.19^{C}
15		23.23^{A}	24.39^{A}	4.88^{B}	5.14^{BC}
30		22.33^{AB}	23.77^{AB}	6.66^{A}	6.14^{AB}
45		20.57^{BC}	20.32^{C}	7.35^{A}	7.49^{A}
CV (%)		7.00	8.36	13.55	19.50
P value		0.0056	0.0059	< .0001	0.0008
LSD		1.84	2.30	0.96	

3.3.4. Haulm Yield

In Hamedo 1 and Hamedo 2 sites, N fertilizer application alone affected haulm yield, but earthing up alone and in combination with N fertilizer did not (Table 5). In both research sites, the best haulm yield was obtained from the application of 45 kg N ha^{-1} but this did not give any different yield than that at 30 kg N ha^{-1}. In both sites, the lowest yields were obtained from the plots that were not fertilized with N fertilizer. In Hamedo 1 and Hamedo 2, application of 45 kg ha^{-1} N fertilizer increased yield by70.53% and 78.76% over unfertilized plots, respectively.Continuous increase in N fertilizer rates at both research sites showed continuous increase in haulm yield. High N fertilizer application is a need to achieve an improved fodder cowpea yields [34]. Similarly, for the present work, Tekulu et al.[6] have found that the use of high amounts of N fertilizer promotes plant vegetative growth and accordingly increases haulm yield. The reason why earthing up did not increase haulm yield is that earthing up practice mostly plays a major role in the creating suitable environment for thepegs that produces pods and thereby increases pod yield and kernel yield.

3.3.5. Pod Yields

Both of separate individual application of earthing up practice and N fertilizer andtheir combined application significantly affected pod yield for bothexperimental sites of Hamedo1 and Hamedo2 (Table 6). Accordingly, earthing up in combinationwith 15 kg ha^{-1} N fertilizer providedan inspiring pod yield. In research siteHamedo 2, there was no significant difference in pod yield between combined application of earthing up with 15 kg ha^{-1} N fertilizer, and earthing up with 30 kg ha^{-1} N fertilizer. The lowest yields were obtained from plots that did not receive earthing up and N fertilizer.In Hamedo 1 and Hamedo 2 trial sites, application of earthing up with 15 kg ha^{-1} N fertilizer increased yields by 57.73% and 55.97%, respectively, than plots received combined application of earthing up and 45 kg ha^{-1} N fertilizer.Earthing up increases pod yield by combining with starter N. It is known that most legume crops require N fertilizer in the early stages of growth until they produce their own N from the atmosphere. Except for the early legume growth, the main source of their food is the N they have produced from the atmosphere through their nodules. Earthing up prevented the pods from being attacked by insects, prevents from being exposed to sunlight and allow easily peg penetrationand thus resulted in an improved groundnut pod yield. Groundnut yield can increase with timely application of earthing up [35]. Positive interaction of starter N fertilizer and earthing up practice has played a good role in increasing the yield of groundnut crop. In support of the present findings, the work reported by Wakjira et al.[36] revealed better anchote yields using earthingup agronomic practice. According to the correlation result, there is a significant association between the number of pods per plant, the number of seeds per plant, the weight of seeds per plant, and the yields of pods and kernels. This demonstrated that as one parameter got higher, the other one followed the trend, and vice versa (Table 7).

Table 6. Response of pod yield and kernel yield to earthing up and N fertilizer.

Earthing up types	N (kg ha^{-1})	Pod yield (kg ha^{-1})		Kernel yield (kg ha^{-1})	
		Hamedo 1	Hamedo 2	Hamedo 1	Hamedo 2
NEU	0	2.61^{CD}	2.70^{D}	1.59^{E}	1.81^{C}
NEU	15	3.39^{B}	3.55^{B}	2.13^{BC}	2.35^{B}
NEU	30	2.81^{C}	3.04^{C}	1.88^{CD}	2.13^{BC}
NEU	45	2.54^{D}	2.67^{D}	1.54^{E}	1.84^{C}
EU	0	2.82^{C}	2.95^{CD}	1.64^{DE}	1.90^{C}
EU	15	3.84^{A}	4.18^{A}	2.60^{A}	3.07^{A}
EU	30	3.34^{B}	3.98^{A}	2.24^{B}	2.88^{A}
EU	45	2.45^{D}	2.68^{D}	1.52^{E}	1.75^{C}
CV (%)		4.32	5.80	8.09	10.87
P value		0.003	0.03	0.036	0.014

LSD	0.22	0.32	0.26	0.42
Earthing up types				
NEU	2.84^{B}	2.99^{B}	1.78^{A}	2.03^{A}
EU	3.11^{A}	3.45^{A}	2.00^{B}	2.40^{B}
CV (%)	4.32	5.80	8.09	10.87
P value	< .0001	< .0001	0.003	0.002
LSD	0.11	0.16	0.13	0.21
N (kg ha^{-1})				
0	2.71^{C}	2.83^{C}	1.61^{C}	1.85^{B}
15	3.62^{A}	3.87^{A}	2.36^{A}	2.71^{A}
30	3.08^{B}	3.51^{B}	2.06^{B}	2.50^{A}
45	2.50^{D}	2.68^{C}	1.53^{C}	1.79^{B}
CV (%)	4.32	5.80	8.09	10.87
P value	< .0001	< .0001	<.0001	<.0001
LSD	0.16	0.23	0.19	0.29

3.3.6. Kernel Yield

In the trial plots (Hamedo 1 and Hamed 2), kernel yield results for groundnut showed a significant effect of earthing up and N fertilizer both in separate individual applications and in combined applications (Table 6). Average highest kernel yields of 2.60 t ha^{-1} for Hamedo 1 and 3.07 t ha^{-1} for Hamedo 2 were obtained in the plots with earthing up and 15 kg N ha^{-1}. The lowest average kernel yields, with 1.52 t ha^{-1} for Hamedo 1 and 1.75 t ha^{-1} for Hamedo 2, were obtained from the earthing up plots that received application of 45 kg N ha^{-1}, without significant yield difference with plots with no earthing up practice and no fertilizer. In the Hamedo 1 and Hamedo 2 test areas, applying 15 kg ha^{-1} N fertilizer to the earthing up soil increased the yield by 70.05% and 75%. 43%, respectively, relative to earthing up plots that received 45 kg N ha^{-1}. This finding revealed that earthing up with starter N fertilizer increases kernel yield. It is known that most legume plants require N fertilization during the initial growth period until they can produce N from the atmosphere. Most of the legumes' N needs come from the atmosphere via N fixation through legume nodules. Additionally, earthing up allows the pegs to penetrate the soil and provides the right environment for pods development, protecting the pods from insects, protecting the pods from sunlight and ultimately ensuring high grain yields. Therefore, effective use of interaction of starter N fertilizer with earthing up had a significant effect on improving groundnut yields.Coinciding with current findings, Rima [37] reported improvement in carrot yield from integrated application of earthing up and 120 kg ha^{-1} potassium (K) fertilizer.Application of combined use of natural manures and man-made fertilizers along with earthing up played a major role in increasing potato yield [38].For groundnut crop cultivated in

Hamedo 1 and Hamedo 2 sites, integrated application of soil earthing up and starter N fertilizer has resulted in positive and strong correlations between number of pods per plant, number of seeds per plant, weight of seeds per plant, pod yield and kernel yield(Table 6). According to the correlation result, there is a significant association between the number of pods per plant, the number of seeds per plant, the weight of seeds per plant, and the yields of pods and kernels. This demonstrated that as one parameter got higher, the other one followed the trend, and vice versa (Table 7). Because of kernel yield is measured from the cumulative effect of seeds produced in individual plants the positive and strong relationship between yield components is decisive.

Separate application of earthing up also brought a significant effect on the kernel yield of groundnut (Table 6). Groundnut yield from earthing up plots had higher kernel yield relative to no earthing up plots. Confirming the present results, Ahmad et al. [14] found improved yield when earthing up is applied for different groundnut varieties. Application of earthing up which is not overlaps with flowering period of groundnut increases kernel yield [16]. In support of the present findings, the work reported by Wakjira et al. [36] observed better anchote yields using earthing up agronomic practice. Another similar work by Kugedera et al. [38] and Doboch et al. [39]demonstrated that earthing up practices increased the marketable yield of potato tubers.Covering tuber crops with soil protects them from insect attack and exposure to sun and thus increases yield [36]. Contrary to the current findings, Desmae et al. [40] found that using soil earthing up did not increase groundnut yield but incurred unwanted expenses and reduced the returned profits.

Similar to the earthing up practices, the kernel yield of groundnut is also significantly affected by the separate application of N fertilizer (Table 6). Nitrogen fertilizer at the dose of 15 kg N ha^{-1} was found an optimum rate for producing an inspiring groundnut kernel yield.According to the research work of Tekulu et al. [6], they obtained better groundnut yield using 15 kg ha^{-1} N fertilizer. A small application of N, which can be called starter N, significantly increases cowpea yield [34]. Application of large amounts of N to soybean plants reduces N fixation capacity and thereby reduces yield [41]. This study was in good agreement with those reported by Getachew Gebrehana and AbebleDagnaw [33], Amante et al. [42], and Dabessa et al. [43] who showed that soybean production is affected by starter nitrogen use.In a study by Scott Tubbs et al. [44], in contrast to the current findings, application of starter N fertilizer did not cause any significant changes in groundnut yield.

3.4. Economic Feasibility

Under A partial and marginal analysis of adjusted groundnut grain yield with respect to soil earthing up and N fertilizer rates is shown in Table 8.Partial and marginal analysis of groundnut grain yields indicates that there are differences in net benefit and marginal rate of return between the treatments. As a result, soil earthing up plots treated with 15 kg ha^{-1} N fertilizer produced the highest net benefit and marginal rate of return. In Hamedo site 1, the highest net benefit was 1740.40US$ ha^{-1}, with an acceptable marginal rate of return (MRR) of 340%; in Hamedo site 2, the highest net benefit was 2158.73US$ ha^{-1}, with an MRR of 6740%. Experimental plots without earthing up soils that received 15 kg ha^{-1} N fertilizer were shown to have the best marginal rate of return and optimum net benefits, similar to the plots with earthing up soils that received 15 kg ha^{-1} N fertilizer. In cases where two treatments exhibit an acceptable rate of return, the treatment offering the greatest net benefit is ultimately a recommendation. Therefore, it is recommended that farmers cultivate groundnuts using a combination of soil earthing up and 15 kg ha^{-1} of starter N fertilizer.

Hamedo 1										
	DF	DM	PH	NB	NP	NS	WS	HY	PY	KY
DF	1									
DM	-0.05^{NS}	1								
PH	0.22^{NS}	-0.13^{NS}	1							
NB	0.34^{NS}	0.22^{NS}	0.79***	1						
NP	0.16^{NS}	-0.17^{NS}	0.20^{NS}	0.17^{NS}	1					
NS	0.16^{NS}	-0.17^{NS}	0.20^{NS}	0.17^{NS}	1***	1				
WS	0.16^{NS}	-0.17^{NS}	0.20 ^{NS}	0.17^{NS}	1***	1***	1			
HY	0.21^{NS}	0.13^{NS}	0.81***	0.74***	0.04^{NS}	0.04^{NS}	0.04^{NS}	1		
PY	-0.11^{NS}	-0.33^{NS}	-0.11^{NS}	-0.23^{NS}	0.64***	0.64***	0.64***	-0.37^{NS}	1	
KY	-0.08^{NS}	-0.36^{NS}	0.09 ^{NS}	-0.09^{NS}	0.71***	0.71***	0.71***	-0.15^{NS}	0.90***	1
Hamedo 2										
	DF	DM	PH	NB	NP	NS	WS	HY	PY	KY
DF	1									
DM	0.35^{NS}	1								
PH	0.56**	0.29^{NS}	1							
NB	-0.01^{NS}	0.15^{NS}	0.63***	1						
NP	-0.36^{NS}	0.20^{NS}	-0.24^{NS}	-0.06^{NS}	1					
NS	-0.36^{NS}	0.20^{NS}	-0.24^{NS}	-0.06^{NS}	1***	1				
WS	-0.36^{NS}	0.20^{NS}	-0.24^{NS}	-0.06^{NS}	1***	1***	1			
HY	0.29^{NS}	0.17^{NS}	0.65***	0.57**	-0.13^{NS}	-0.13^{NS}	-0.13^{NS}	1		
PY	-0.40^{NS}	-0.06^{NS}	0.04^{NS}	0.15^{NS}	0.54**	0.54**	0.54***	-0.23^{NS}	1	
KY	-0.30^{NS}	0.02^{NS}	0.13^{NS}	0.07^{NS}	0.59**	0.59***	0.59***	-0.09^{NS}	0.87***	1

Table 7. Pearson's correlation coefficients (r) for various groundnut parameters.

Stars indicate significant effects *p (probability level) ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001, NS = non-significant, DF = days to 50% flowering, DM = days to 90% maturity, PH = plant height, NB = number of branches per plant, NP = number of pods per plant, NS = number of seeds per plant, WS = weight of seed per plant, HY = haulm yield, PY = pod yield, KY = kernel yield and SH = shelling percentage

Table 8. Partial and marginal analysis for Kernel yield of groundnutunder earthing up N fertilizer at the Mereb Leke district (Hamedo 1 and Hamedo 2 trial sites).

Hamedo 1							
TRT	TVC (US$ ha^{-1})	KY (t ha^{-1})	AKY (t ha^{-1})	GB (US$ ha^{-1})	NB (US$ ha^{-1})	DA	MRR (%)
NEU + No Fertilizer	0	1.59	1.43	1118.04	1118.04	-	-
NEU + 15 kg N Fertilizer	29.62	2.13	1.92	1497.75	1485.03	11.82	1182
NEU + 30 kg N Fertilizer	42.34	1.88	1.69	1321.96	1296.52	D	
NEU + 45 kg N Fertilizer	55.06	1.54	1.39	1082.88	1044.72	D	
EU + No Fertilizer	75.12	1.64	1.48	1153.20	1078.08	D	
EU + 15 kg N Fertilizer	104.74	2.6	2.34	1828.24	1740.40	3.40	340
EU + 30 kg N Fertilizer	117.34	2.24	2.02	1575.10	1474.66	D	
EU + 45 kg N Fertilizer	130.18	1.52	1.37	1068.82	955.54	D	
Hamedo 2							
TRT	TVC (US$ ha^{-1})	KY (t ha^{-1})	AKY (t ha^{-1})	GB (US$ ha^{-1})	NB (US$ ha^{-1})	DA	MRR (%)
NEU + No Fertilizer	0	1.81	1.63	1118.04	1272.74	-	-
NEU + 15 kg N Fertilizer	29.62	2.35	2.12	1497.75	1652.45	12.82	1282
NEU + 30 kg N Fertilizer	42.34	2.13	1.92	1321.96	1497.75	D	
NEU + 45 kg N Fertilizer	55.06	1.84	1.66	1082.88	1293.83	D	
EU + No Fertilizer	75.12	1.9	1.71	1153.20	1336.02	D	
EU + 15 kg N Fertilizer	104.74	3.07	2.76	1828.24	2158.73	6.74	674
EU + 30 kg N Fertilizer	117.34	2.88	2.59	1575.10	2025.13	D	
EU + 45 kg N Fertilizer	130.18	1.75	1.58	1068.82	1230.55	D	

Trt = treatment, TVC = total variable cost, KY = kernel yield, AKY = adjusted kernel yield, GB = gross benefit, NB = net benefit, DA = dominance analysis, D = dominated, MRR = marginal rate of return, urea fertilizer price = 39 US$ 100 kg^{-1}, fertilizer transport cost = 1.25 US$ 100 kg^{-1}, fertilizer application cost = 15.65US$ ha^{-1}, groundnut kernel yield price = 781.3US$ t^{-1}, labor cost = 3.13US$ $person^{-1}$ day^{-1}, one US$ = 32 Ethiopian birr.

4. CONCLUSION

The results of the study demonstrated that not all of the treatments had an impact on groundnut flowering or maturity. Additionally, plant height, number of branches per plant, number of pods per plant, number of seeds per plant, seed weight per plant, and haulm production were not significantly impacted by soil earthing up. It had no effect on the previously mentioned groundnut characteristics because soil earthing up usually contributes significantly to creating an environment that is favorable for the pod-producing pegs, hence increasing pod and kernel yields. However, the use of nitrogen fertilizer alone had a substantial impact on plant height, number of branches per plant, number of pods per plant, number of seeds per plant, seed weight per plant, and haulm yield. This led to increased haulm yields, increased plant height, and more branches per plant in groundnut plots treated with a higher dosage of nitrogen fertilizer. Plant height, branch number and haulm yield all increased as a result of a more durable nitrogen nutrients within the soil brought about by greater nitrogen rates. Additionally, because it encourages cell division and elongation, N fertilizer is the most crucial nutrient for plants in terms of boosting growth. Fortunately, groundnut pod and kernel yields were significantly affected by the use of soil earthing up alone, nitrogen fertilizer application alone, or a combination of both. By protecting the pods from pests, keeping them out of the sun, and making it easier for pegs to penetrate the soil, soil earthing up enhanced groundnut productivity by increasing the yield of pods and kernels. In conjunction with soil earthing, 15 kg ha^{-1} N was applied to boost pod and kernel yields. Impressive yields were obtained with low nitrogen rates because most legume crops require nitrogen fertilizer early in their development before they can produce nitrogen from the atmosphere on their own. Legumes' main source of nutrition, aside from their early growth, is the nitrogen that their nodules fix from the atmosphere. The results of the agronomic and economic analyses show that groundnut yields and profits are significantly increased when N fertilizer and the earthing up are combined. Therefore, to increase groundnut production and receive more financial advantages, producers should consider the combined application of 15 kg ha^{-1} N fertilizer and earthing-up practice.

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