Plant Archives Vol. 24, No. 2, 2024 pp. 415-421 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.058

INVESTIGATION ON SOIL AND GROUNDNUT PLANT CHARACTERISTICS FOR THE DESIGN AND DEVELOPMENT OF GROUNDNUT DIGGER CUM INVERTER

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(Date of Receiving-16-02-2024; Date of Acceptance-03-05-2024)

ABSTRACT

Groundnut, holds a significant position in Indian agriculture, groundnut is a vital crop contributing to both the economic and nutritional aspects of the country. Groundnut holds immense importance due to its versatility, serving as a source of edible oil, protein-rich food and raw material for various industrial applications. Groundnut harvesting is labor-intensive, exacerbated by labor scarcity and weather constraints. Farmers seek low-cost, labor-efficient solutions like tractor-mounted diggers. Existing options are costly and unsuitable for small farms. A mini tractor-operated groundnut digger cum inverter is proposed to address these challenges, aiming to reduce costs, labor, and enhance efficiency. The design and development of a groundnut digger cum inverter represent a crucial innovation aimed at streamlining and enhancing the efficiency of groundnut cultivation processes. The design of harvesting, conveying, and stripping equipment for groundnut cultivation relies heavily on understanding the physical properties of both soil and groundnut plants. Factors such as soil strength, bulk density, moisture content, as well as plant dimensions and characteristics, influence parameters like digging depth, blade angle, conveyor speed, and inverter spacing. Key considerations in the design and development of this innovative equipment include its structural robustness, adaptability to varying soil conditions, operational simplicity and compatibility with different tractor models. Furthermore, the implement must prioritize safety features to ensure operator protection during operation. The study focuses on soil and groundnut plant properties crucial for designing a tractor-mounted groundnut digger. Soil analysis revealed sandy loam soil with a moisture content ranging from 13.28% to 16.03% and a bulk density of 1.18 g/cm³. Soil resistance was measured between 278.80 k Pa to 398.70 k Pa. Groundnut crop properties, including plant habit, height, canopy width, pod depth, root length and pod count, were assessed for varieties GJG-32, GJG-33, GG-8, and GJG-9. The crop's maturity ranged from 95 to 124 days. Variations in plant characteristics such as height (17-43 cm), pod zone depth (5-11 cm), and root length (12-20 cm) were observed. These findings provide valuable insights for optimizing groundnut digger design and operation.

Key words : Groundnut, Digger cum inverter, Soil properties, Plant properties.

Introduction

Groundnut is one of the most important and economical oilseed crops, which are mostly grown in tropical to the sub-tropical area. It's mostly grown for oil, protein, and carbohydrates (Abdzad Gohari and Noorhosseini Niyaki, 2010). It is the 13th most important food crop and 4th most important oil seed crop of the world (Lakhani and Vagadia, 2023). The multiple uses of the groundnut make it an excellent cash crop for domestic markets as well as foreign trade. The groundnut reached Eastern Asia from South America and from there came to India on the East Coast of Madras State by Spaniards (Reddy, 1988).

Groundnut is a tropical crop, which requires a long and warm growing season. The minimum and maximum temperature requirements of groundnut are not well established but, it germinates more quickly within a range of 20-35^{0}C with optimum temperature between 30-33^{0}C for most rapid germination and seedling development (Singh, 2004). Low temperature at sowing delays germination and increases seeds and seedling diseases (Singh and Oswalt, 195).

Groundnut is grown on nearly 327 lakh hectares in the world with an annual production of 539 lakh tonnes with the productivity of 1648 kg per hectare (www.fao.org). With annual all-season coverage of and the average productivity is 1648 kg/ha in 2022.

Groundnut is a primary oilseed crop in India, holding the top position in terms of cultivation area and second place in terms of production following soybean. In the 2020-21 agricultural cycle, China demonstrated preeminence in groundnut production, yielding 18.36 million tonnes, followed by India with 10.24 million tonnes. Nigeria contributed 4.61 lakh tonnes, the United States 2.90 million tonnes and Sudan 2.36 million tonnes. These figures represent proportional shares of 34%, 19%, 9%, 5% and 4%, respectively, towards the cumulative global groundnut production totaling 53.97 million tonnes (www.agricoop.gov.in).

Most of it is cultivated by small and medium farmers in the semi-arid zones of India (Govindaraj and Mishra, 2011). The major unit operation in groundnut cultivation is seedbed preparation, sowing, fertilizer application, plant protection, irrigation, harvesting and threshing. Harvesting is one of the major operations, which accounts for 23% of the total cultivation cost (Seshadri, 1962).

Harvesting and threshing of the groundnut are the most important and labor-intensive operations in groundnut cultivation. In general, the period during which groundnut is harvested is warmer weather with high temperatures; therefore, laborers experience bad weather to work. So the availability of labor is very difficult at the harvesting stage. During peak seasons, due to the non-availability of labor, harvest delays occur and lead to high threshing losses. In addition, the migration of the agricultural labor force from the rural areas aggravated the problems for the farmers.

In contemporary agricultural practices, there is a prevailing preference among farmers for machinery capable of executing operations at low cost and with minimal labor involvement. Consequently, there arises a demand for a cost-effective tractor-mounted implement that can perform multiple tasks such as digging, conveying, and aligning groundnut crops into a single row during a single pass. Although, various tractor-operated groundnut diggers have been developed and are accessible in the market, their adoption remains constrained due to factors like limited land holdings and high capital outlay, rendering them economically unviable for small-scale and marginalized farmers. Research efforts on the design and advancement of tractor-operated groundnut diggers are scant, resulting in their limited popularity and commercial availability. Given the significant expense associated with harvesting operations, there exists a pressing need for a compact tractor-operated groundnut digger cum inverter capable of meeting the needs of small-scale farmers, reducing operational costs, labor and ensuring timely execution of tasks.

The proposed machine not only reduces the drudgery of humans and animals, but it is also possible to enhance the cropping intensity, precision of application, and timeliness. All these operations finally improve the efficiency in the utilization of different crop inputs and also minimize the losses at various stages of crop production. The main objective of this study is to determine and understand the soil and crop parameters which influences the harvesting of groundnut and should consider while designing the groundnut digger.

Engineering properties are useful and necessary in the design and operation of various farm equipment employed for agricultural operations (Sahay and Singh, 1994).

The important engineering/physical properties of soil and groundnut crop namely; for soil: soil type, soil moisture content, bulk density and cone index, for groundnut crop: variety, inter row spacing, plant height, no of branch per plant, plant population, pod zone depth, pod spreading radius, no. of pods per pant, taproot length which are directly related to machine development, were determined in the present study.

Basic information on these properties is of great importance and helps engineers and scientists with equipment development and its efficient operation. The knowledge of engineering properties is important for the design, development, and efficient operation of digger cum inverter.

Materials and Methods

The chapter describes the methodology used for the design and development of a mini tractor operated groundnut digger-cum inverter. The details of materials used for the fabrication of the equipment, experimental methodology for field evaluation of the developed equipment and measurement techniques adopted during the investigation were described in the following sections.

Experimental site

The geographical location of the experimental plot located in Junagadh Agricultural University is 21°29’18"N and 70°25’46"E with an elevation of 74.76 m above the mean sea level. The average annual temperature is 29.6ºC and the mean temperature ranges from 28 to 38ºC reaching a peak of 41ºC in May. The average rainfall, relative humidity, and wind speed of the test location are 312 mm, 37% and 26 km/h per year, respectively. The soil of the experimental plot is clay loam (Patel *et al*., 2023). The field was sown with locally popular groundnut varieties of GJG-32, GJG-33, GG-8 and GJG-9 for study.

Properties of soil for the design of groundnut digger-cum-inverter

Type of soil

The type of soil affects the draft requirement, as well as the maximum penetration depth of the tool. The digging blades of the groundnut digger cum inverter interact with soil to uproot the groundnut plants. Therefore, soil properties directly affect the digging performance of groundnut digger. Hence the following properties of the soil were evaluated before designing the groundnut digger-cum inverter.

1. Soil moisture content
2. Soil bulk density
3. Soil strength

Soil moisture content

Soil moisture content plays a vital role in the growth and development of groundnut (Seshadri, 1962; Singh, 2004). The soil moisture content tends to significantly affect the digging efficiency, pod losses, draft requirement of the implement (Sahay and Singh, 1994; Patel *et al*., 2023). The soil moisture content was determined by the oven drying method. Five samples were collected randomly from the test plot and kept in an oven at 105 ºC for 24 hours. The moisture content was calculated as per the given formula: (IS: 2720 - 2 - 1973).

$$Moisture\,Content\,(\%) = \frac{W - W_d}{W_d} \times 100$$

Where,

MC = moisture content in dry basis, %

W = wet weight of sample, g

W_d = weight of dry sample, g

Bulk density of the soil

Bulk density of the soil influences the tool parameters and draft requirement (Mouazen and Ramon, 2002). Metallic core sampler was used to take soil samples in the test field. The bulk density of soil is the ratio of dry weight of soil to its corresponding volume of the core sampler. The bulk density was determined by the fallowing formula: (Punmia *et al*., 2009).

$$Bulk\ Density = \frac{W}{V}$$

Where,

W = dry weight of sample, g

V = volume of the core sample, cm^3

Soil strength

The cone index is a measure of penetration resistance of the soil, which is useful in the calculation of motion resistance and power required by the tractor with a digger to propel itself without generating any drawbar pull. The cone index of the soil was measured at five different locations up to the depth of 100 mm by using a Vicksburg cone penetrometer [Fig. 2 (c)]. The mean values were calculated.

Properties of groundnut crop for the design of groundnut digger-cum-inverter

The crop parameters, which influence groundnut harvesting were plant height, inter row spacing, plant population, pod zone depth, pod spreading diameter, number of pods per plant, taproot length, taproot diameter and pod-vine ratio. The crop parameters were collected before the harvesting of the crop. These crop parameters were discussed in the following sub-sections.

Variety

Crop variety is an important parameter, which influences mechanical digging since the growth factor and foliage vary for each variety. Therefore, different varieties (Fig. 3) of groundnut crop were selected for the study, which is generally grown in this region.

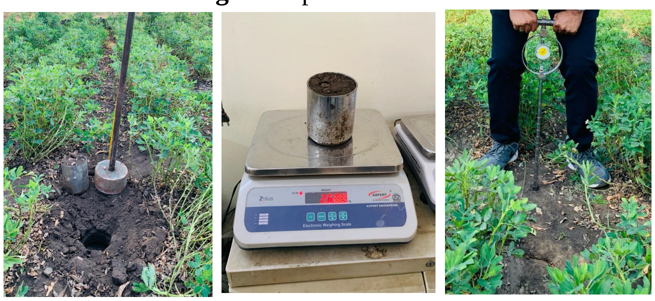
Inter row spacing

The inter row spacing of groundnut was relevant to decide the working width of the groundnut digger. It was measured using a measuring tape at five randomly selected rows.

Plant height

The plant height of the groundnut crop may vary with variety, soil texture, growing season, spacing between the plants, and climatic conditions. The plant height of GJG-32, GJG-33, GG-8 and GJG-9 varieties was measured by selecting plants randomly in the field with the help of the steel rule at the time of harvesting as

Fig. 1 : Experimental site.



(a). Bulk density using core cutter (b). Weight of soil (c). Cone penetrometer

Fig. 2 : Measurement of soil parameters.

Pod spreading radius

The pod spreading was relevant for deciding the working width of the digging blade. The pod spreading of twenty plants selected at random was measured using a scale by digging the soil adjacent to the plant on both sides. The mean pod spreading was determined.

Root length

The root length of the groundnut plant was determined during harvesting through manual excavation of the soil adjacent to the plant's root system, extending to the deepest point of root penetration. The plant root lengths were measured with the help of the steel rule in the test plot.

Plant population

The plant population was determined by counting the number of plants available in a one-meter square area at different locations by using the 1 m^2 frame. The plant population was used to determine the volume of the crop handled by the digger.

GG-8 GJG-9 GJG-32 GJG-33

Fig. 3 : Varity of groundnut (Source: www.jau.in).

shown in Fig. 4.

Width of plant canopy

The width of plant canopy of the groundnut crop depends on the density of the plants and varieties. The plant canopy width of GJG-32, GJG-33, GG-8 and GJG-9 varieties was measured by selecting plants randomly in the field with the help of the steel rule at the time of harvesting as shown in Fig. 5.

Pod zone depth

The pod zone depth was relevant to decide the depth of operation. The pod zone depth of five randomly selected plants was measured using a scale by digging the soil adjacent to the plant. The average value of pod zone depth was determined.

Fig. 4 : Plant height.

Fig. 5 : Plant canopy.

Fig. 6 : Number of pods per plant.

Number of pods per plant

The number of pods per plant is an important parameter in the determination of digging efficiency and percentage of pod damage. The number of pods per plant was counted from twenty randomly selected plants. The average value for the number of pods per plant was calculated.

Results and Discussion

This chapter presented the soil and groundnut plant properties results obtained for the design and development of tractor mounted groundnut digger.

Impact of soil properties on the design of groundnut digger cum inverter

The soil of the experimental field was determined as clay loam soil. The correlation between soil physical and mechanical properties and machine parameters is crucial in the design of any digging system. The independent soil moisture content and the dependent parameters bulk density, soil resistance. The relationships among these parameters have been observed to impact the efficiency of the digger, particularly with respect to digging efficiency and the power demand during machine operation in field conditions.

Soil moisture content at harvesting stage

Before conducting each experiment, the soil moisture content was determined randomly at five different locations and at different intervals to see the effect of soil moisture content on other parameters. The observed values were varies from 13.28 – 16.03% with an average of 14.65% at the time of crop harvesting. The recorded results were close to the results obtained by Zhichao *et al.* (2010).

Table 1 : Soil properties.

S. no.	Parameter	Average
1	Moisture content (%)	14.65
2	Bulk density (g/cm^3)	1.18
3	Soil strength (kPa)	338.07

Bulk density at harvesting stage

Bulk density stands as a fundamental parameter for evaluating soil compaction and health status. Its influence extends to critical soil functions such as water infiltration, root zone penetration, water holding capacity, soil pore structure, nutrient accessibility to plants and microbial activity within the soil ecosystem. These parameters further influences the key soil processes and productivity. Soil bulk density measured at five different locations of the experimental plot with replications for studying the effect of soil bulk density on other parameters. The observed values were obtained in the range of 1.03 – 1.34 g/cm^3 with mean value of 1.18 g/cm^3 as shown in Table 1.

Soil Resistance at harvesting stage

Soil resistance is an indication of soil hardness measured by penetrating the cone penetrometer in to the soil. Before conducting the each experiment, soil resistance was measured for each experimental plot randomly at five locations for studying the effect of soil resistance on the other parameters (ASAE: S313.3 Standards, 2004). The observed values were in the range of 278.80 kPa to 398.70 kPa with an average value of 338.07 kPa.

Physical properties of groundnut crop and their impact on groundnut digger cum inverter

About 90% of the groundnut in India is sown in the *Kharif* season under rainfed conditions but the yield is low because of more vegetative growth, high weed infestation and more susceptibility to insects, pests and disease. Groundnut is cultivated during the *rabi* season on a restricted scale in regions characterized by mild winters and night-time temperatures remaining above 15°C. This crop is usually raised in a rice fallow situation to utilize the residual moisture after the harvest of rice. Groundnut needs good sunshine and high temperature to produce more pods. Summer, is therefore the ideal season for groundnut cultivation wherever irrigation facilities are

Table 2 : Crop parameters of selected groundnut crop varieties.

S. no.	Properties	GJG-32	GJG-33	GG - 8	GJG - 9
1.	Condition of sowing	Kharif rainfed	First forth night of January	Rainfed	Rainfed
	Maturity days	113 - 124	95 -122	104 – 107	101 - 109
2.	Plant habit	Erect	Erect	Spanish bunch	Spanish bunch
3.	Plant height (cm)	30 – 34	17 – 19	39 – 43	32 -36
4.	Inter row spacing (cm)	45 × 10	30 × 10	45 × 10	45 × 10
5.	Width of plant canopy (cm)	42 - 46	40 - 44	39 - 43	41 - 45
6.	Pod zone depth (cm)	6 - 11	6 - 9	5 - 8	7 - 9
7.	Pod spreading radius (cm)	10 - 12	8 - 11	7 - 10	7 - 11
8.	Root length (cm)	13 -15	12 – 16	16 – 20	15 - 17
9.	Plant population	16 - 20	18 - 22	17 - 19	16 - 19
10.	Number of pods per plant	26 – 32	19 – 27	15 – 24	9 - 17
11.	No. of branch	7 – 10	5 – 8	6 – 8	4 - 7

available and the soil is suitable.

Plant physical properties are expected to influence on the design of machine. These properties ascertain the range of machine parameters to be used while operating the machine. Hence, plant physical properties are used in design of groundnut digger. The parameters such as plant height, plant canopy width, root length, number of pods per plant, pod location depth and number of branches of each plant were determined for the locally available popular varieties of GJG-32, GJG-33, GG-8 and GJG-9. The interactions between these parameters affected the performance of digging and conveying system in terms of digging, picking, conveying and power requirement to operate the machine at given physical and mechanical properties of the crop.

The physical characteristics of the different varieties of groundnut crop were investigated (Table 2). Groundnut crop is suitable in rainfed season and also suitable in kharif season wherever irrigation facilities are available. The maturity of groundnut crop was ranged between 95 – 124 days, which are similar to 3 – 3.5 month.

GJG-32 and GJG-33 have erected type plant habit and GG-8 and GJG-9 have a spanish bunch type plant habit. Inter row spacing for GJG-32, GG-8 and GJG-9 was 45 × 10 cm and GJG-33 having 30 × 10 cm spacing which is dependent to groundnut varieties also suitable for increase the yield. Width of plant canopy was ranged between 39 – 46 cm for selected groundnut varieties. The plant height of groundnut crop was varied between 17 – 43 cm for selected groundnut varieties. The pod zone depth of the selected groundnut varieties was varied from 5 - 11 cm with an average depth of 8 cm.

The root length of groundnut crops ranged from 12 to 20 cm, with an average depth of 16 cm, across selected varieties including GJG-32, GJG-33, GG-8 and GJG-9. Meanwhile, the plant population of groundnut varied from 16 to 22 plants per square meter, with each plant having an average of 21 pods, among the same varieties.

Conclusion

The physical properties of the groundnut varieties namely, GJG-32, GJG-33, GG-8 and GJG-9 were investigated in this study. Various studies examining the physical properties of groundnuts were explored in this review, unearthing a wealth of intriguing findings and insights. The analysis of soil and crop parameters is crucial for the development of tractor operated groundnut digger. Through this analysis, various soil and crop factors that affect the performance and efficiency of groundnut digger have been identified. By considering the various soil and crop parameters, manufacturers can design groundnut diggers that are efficient, cost-effective, and environmentally sustainable, contributing to the overall growth and development of the agricultural industry. As equipment design crucially depends on the physical and engineering properties of groundnut plant.

Acknowledgement

The authors would like to thank the College of Agricultural Engineering and Technology, Junagadh Agricultural University for co-operation and provided necessary facilities to achieve the desired goals of this research.

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