E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(8): 239-245
Received: 03-06-2024
Accepted: 08-07-2024

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Studies on biometric properties of lathyrus crop and energy analysis of developed lathyrus harvester

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i8d.1224

Abstract
Grass pea or *Lathyrus sativus* L., is a herbaceous annual plant with a high-branched, ascending, or straggling form. It has a well-developed taproot system, and the rootlets are covered with tiny, cylindrical, branching nodules. Lathyrus crop is the third most important cool-season pulse crop of India, occupying an area of 0.58 million ha with an annual production of 0.43 million tones. The knowledge of physical and engineering properties of the crop plays an important role while designing of different agricultural machines. The physical properties such as plant height stem diameter, number or branches/ plant, number of pods and seeds/ pant, crop density/m^2 of prateek variety along with important engineering properties such as bulk density, true density, angle of repose and crushing resistance were determined. Also energy required by tractor, implement, human and fuel was calculated as indirect and direct source of energy and total energy required was found to be 872 MJ ha^{-1}.

Keywords: Grass pea, *Lathyrus sativus* L., herbaceous annual plant

1. Introduction
Lathyrus, commonly known as *khesari* in local dialects, is a high-protein, cool-season pulse crop cultivated for both food and fodder purposes. It contains 31.9 % protein (Almost having twice the protein in wheat and thrice that of rice), 0.9% fat, 53.9% carbohydrate, 362.3 cal energy, 1.1% crude fiber and 3.2% ash. According to Indian Institute of Pulses Research's vision document, the pulse requirement for the year 2030 is projected at 32 million tons with anticipated annual growth of 4.20%.
The northern and central parts of India are the main territories of lathyrus crop production. It is cultivated primarily in Chhattisgarh, Bihar, Madhya Pradesh, Maharashtra and West Bengal. Chhattisgarh ranked first in the area as well as in production (66.68% and 60.54%), followed by Bihar (13.10% and 16.95%). Madhya Pradesh was ranked third in the area (8.41%), whereas West Bengal was in production (12.19%) respectively. The majority of this acreage (~70%) is shared by Chhattisgarh and the Vidarbha region of Maharashtra. The Chhatisgarh's main cultivation and consumption areas are Raipur, Durg, Ranjandgaon, Kabirdham, Bilaspur, Dhamtari, Raigarh, Mahasamund, Janjgir-Champa and Jashpur.
Campbell (1997) [13] mentioned plant height of lathyrus varies considerably in India and Canada, ranging from 15 to 68 cm in India and 24.5 to 172 cm in Canada. Grela *et al.* (2010) [2] found that plant height was extremely variable and strongly influenced by environmental factors. Donskoy (2013) reported that mainly three factors influence the seed yield in grass pea samples to the greatest extent they were plant weight, number of pods per plant and weight of pods per plant. The harvesting of grass pea is done when plant gets hard and changes colour from green to brownish**.**

2. Materials and methods
2.1 General Description
The two popular varieties of lathyrus (Prateek and Mahateora) in Chhattisgarh were selected. Crop characteristics of lathyrus namely height of plant, number of plant per meter length, number of pods per plants, its agronomic practices and schedule of harvesting was studied.
The plant was sown at Research Farm, Department of Farm Machinery and Power Engineering,

IGKV, Raipur and also at KVK, Pahanda, Durg. The crop was sown by using Seed-cum-Fertilizer Drill which was 2.00 m wide. The gaps maintained between seeds were 300×100 mm.

Fig 1: Sowing operation of lathyrus

Table 1: General details about the selected crop varieties

Name of variety	Description of the variety		
Prateek	Place of released	:	IGKV Raipur
	Year of released	:	2001
	Average yield, qha^{-1}	:	14-15
	Duration of crop, days	:	110-115
	ODAP content%.	:	0.076
Mahateora	Place of released	:	IGKV Raipur
	Year of released	:	2007
	Average yield, qha^{-1}	:	15-16
	Duration of crop, days	:	110-115
	ODAP content%.	:	0.074.

Physical and engineering properties are important in many problems associated with the design of machines and the analysis of the behaviour of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying. The solutions to problems of these processes involve knowledge of the physical and engineering properties. All these parameters were measured and are described below-

2.1.1 Plant height

The plant height of the crop varies from variety to variety, season of sowing the crop and also spacing provided for plant to plant as well as climatic conditions. In the present study plant height for Prateek and Mahateora variety (Local variety) were measured at different stages after sowing i.e.30, 60, 90, 120 DAS (Days after sowing) from the ground level to the top of the plant by randomly selecting plants in the field and measuring their height with the help of a steel ruler having least count of 1 mm at the time of the harvest.

2.2 Plant populations

The plant population indicates the number of plants per square meter (plants/m^2). The plant populations were counted with the help of a square frame having 1 m^2 area from each of the plots after few days of sowing and before the harvesting of the crop, and their average value indicates the plant populations.

2.3 Stem diameter

The stem diameter was measured with the help of a vernier caliper having least count of 0.01 mm. The measurement was taken place at randomly selected 10 plants in each plot. It was done at the three points of the stem and the thickest part was noted for study.

2.4 Numbers of branches

The branches were divided into primary and secondary according to its position and total number of branches was counted in whole plants. The branches near to the main stem are called as primary whereas, the branches appeared from the primary are termed as secondary branches. Both primary and secondary branches were counted together to determine the total number of branches in a plant.

Fig 2: Measurement of plant height

2.5 Bulk density

The bulk density was calculated as the mass of leaves divided by the container volume (Singh and Goswami, 1996, Baryeh, 2002) [3, 4]. A metallic cube box of known dimension 20×20×20 cm^3 was used to measure the bulk density of crop (Fig 5). The box was completely filled by crop up to the top followed by three times tapping and weight was taken with an electronic balance having least count of 1 g. The bulk density was calculated by using the Equation 3.1 (Kushwaha *et al.*, 2015) [14].

$$\text{Bulk density, (kg m}^{-3}) = \frac{\text{Weight of leafs of crop (kg)}}{\text{Volume of box (m}^3)}$$

2.6 True density

The true density is defined as the ratio of mass of the sample to its true volume. It was determined using the toluene (C7H8) displacement method, 50 millilitres of toluene were placed in a 100ml graduated measuring cylinder and 5g seeds were immersed in the toluene (Mwithiga and Sifuna, 2006) [15]. The amount of displaced toluene was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced toluene gave the true density.

$$TD = \frac{Ws}{Tv}$$

Where,
TD = True density, kg/m^3;
Ws= Weight of seed, kg; and
Tv = True volume of seed, m^3.

2.7 Angle of repose: The angle of repose is the angle with horizontal at which the material will stand when piled. The angle of repose measuring equipment consisted of a funnel with a conical shape and a sliding and detachable opening on one end. It was determined using the formula below-

$$\alpha = \tan^{-1}\left(\frac{h}{L}\right)$$

Where,
α = Angle of repose, degree;
h = height of the heap, mm;
L = radius of the heap, mm;

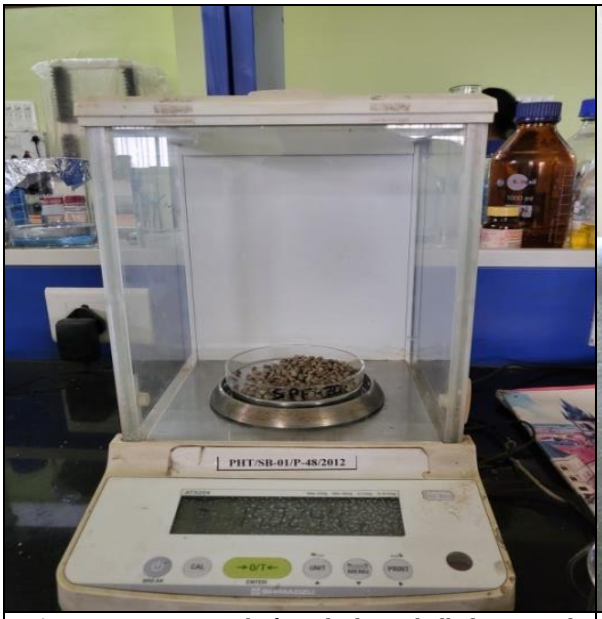

Fig 5: Measuring weight for calculating bulk density and true density of stem and seed of lathyrus

Fig 6: Measuring angle of repose of lathyrus seeds

2.8 Crushing resistance/force

The experiment was carried out to find the rupture force of Lathyrus stem. The texture analyzer (TW+Di) was used for determination of force. The texture analyzer consisted of two primary components: hardware (load cell with a platform to hold sample and moving head for holding probe) and software (Texture Expert) for recording & calculating the test results. Before performing the tests, the machine was calibrated for load and distance for each type of test. The load calibration was done to check whether the load cell was accurate in sensing the force imposed over the sample. Calibrating 50 g were suspended on the crosshead and selected the desired option under T.A. settings. Similarly, calibrated the movement of the cross ensure the compliance of the set deformation (Strain) of the sample. After calibrating the texture analyzer, a sample of crop stem was placed on the platform. Different probes were used for different tests as per settings to generate the force-time curves. (Kingsley *et al.*, 2006) [12]. The force required to rupture or deform was abstracted from the graph shown and procedure repeated for 5 times to get the average mean value.

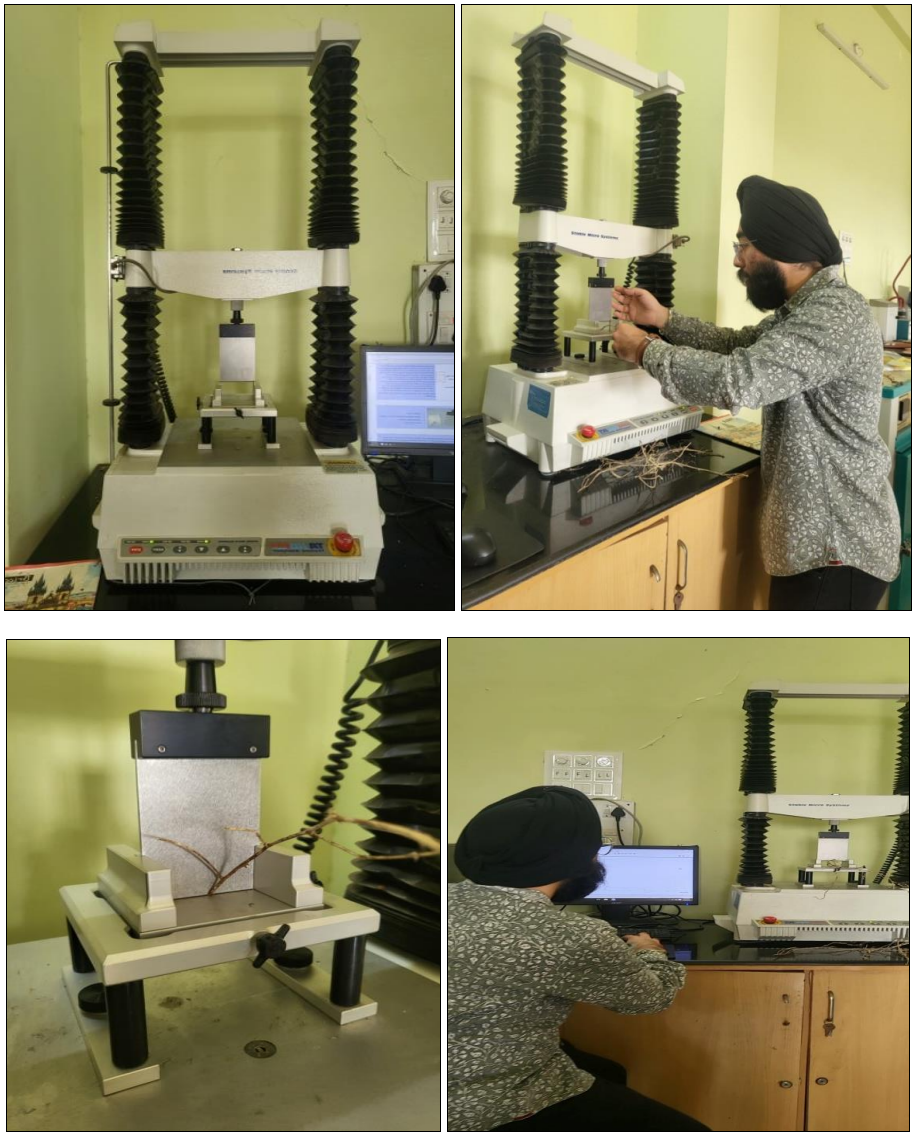

Fig 7: Measurement of crushing resistance of stem in texture analyzer

2.9 Coding according to plant characteristics

Table 2: Coding of characteristics of lathyrus plant on growth habitat and branch arrangement

Coding of plant growth habitat		Coding of branch arrangements	
Code	**States**	**Code**	**States**
1	Prostrate	1	Evenly distributed throughout the whole plant
2	Spreading	2	Mainly on lower part of the plant
3	Semi-erect	3	Mainly in middle part of the plant
4	Erect		

Table 3: Coding of characteristics lathyrus plant on leaflet shape and pod shape

Coding of leaflet shape		Coding of pod shape	
Code	**States**	**Code**	**States**
1	Linear	1	Oblong – elliptical
2	Lanceolate	2	Medium oblong – elliptical
3	Ovate- lanceolate	3	Curved
4	Ovate	4	Beaded
5	Other	5	Board – linear
		6	Board – elliptical
		7	Other

2.10 Energy analysis: Energy from direct sources and indirect sources (Singh and Mittal, 1992) [11]

Energy of man (MJ ha^{-1}) = 1.96 x working hours per ha

Energy of diesel (MJ ha^{-1}) = 56.31 x working hours per ha × fuel consumed (l h^{-1}) Direct energy (MJ ha^{-1}) = Energy of man + energy of diesel

Direct energy = Energy of man + energy of diesel

The indirect energy was obtained from tractor and machinery.

$$\text{Energy of tractor (MJ/ha)} = \frac{68.4 \times \text{weight of tractor} \times \text{working hours per ha}}{\text{life of tractor in hours}}$$

$$\text{Energy of implement (MJ/h)} = \frac{68.4 \times \text{weight of implement} \times \text{working hour per ha}}{\text{life of implement in hours}}$$

Indirect energy = Energy of tractor + energy of machinery

Total energy

Total energy = Direct energy + indirect energy

3. Result and discussions

3.1 Determination of physical properties of lathyrus crop

The height of lathyrus crop, stem diameter, number of branches/plant, number of pods/plant and number of seeds/pod are depicted in Table 4. It was found that height of plant was found in range of 240 mm to 630 mm with a mean of 435.8±6.19 mm. Plant height is an important parameter in deciding the reel height for the developing of the lathyrus harvester. Similar types of results were also reported by in other similar type pulse crop by Manthesh, 2006 [6] and Sushilendra 2016 [7].

The average stem diameter of lathyrus plant was 2.72± 0.38 mm for 50 randomly collected samples. The obtained data was distributed in the range of 2.04 to 3.66 mm. The Number of branches per plant of lathyrus crop was observed as 6.31and it varied in range of 4 to 9.The height of lower branch assisted in deciding the height of cutter bar of developed harvester. The number pods per plant and number of seed per pod at the time of harvest was found in the range of 14 to 26 and 3-6 respectively in selected crop. Similar results were also reported by Rosa and Martin, 2001 [8], Shehadeh *et al.*, 2013 [10], Pandey, 1995 [9].

Table 4: Plant height, stem diameter, number of branches/plant, number of pods/plant and number of seeds/pod of lathyrus plant

Description	Plant height (mm)	Stem diameter (mm)	Number of branches/plant	Number of pods/plant	Number of seeds/pod
Mean	435.87	2.72	6.31	18.75	3.92
Max	630.00	3.66	9.00	26.00	6.00
Min	240.00	2.04	4.00	14.00	3.00
SD	100.71	0.42	1.37	3.09	0.95
CV(%)	23.10	15.75	21.76	16.45	24.34
V(P)	9935.90	0.18	1.85	9.33	0.89
V	10142.90	0.18	1.88	9.52	0.91

Table 5: Plant population/m^2, seed yield, stover yield and harvest index of lathyrus crop

Description	Plant population/m^2	Seed yield, kg/m^3	Stover yield, kg/m^3	Harvest index, %
Mean	24.8	1076.6	2239.1	31.54
Max	27.0	1189.0	2412.0	33.00
Min	22.0	938.0	2025.0	30.00
SD	1.813	81.54	126.706	1.083
CV (%)	7.312	7.574	5.658	3.437
V(P)	3.288	6649.6	16054.54	1.174

3.1.1 Crop stand density or plant population/m^2

It was observed that the crop stand density for lathyrus crop varied from 22 to 27 numbers per m^2 with mean value of 24.8 numbers per m^2.This variation may be due to crop row spacing and germination of seeds sown in observed fields. The data of plant density was used in deciding the collection box capacity of developed prototype.

3.1.2 Seed yield, Stover yield and harvest index of lathyrus plant

The average seed yield, stover yield and harvesting index was observed as 1076.6 kg/m^3, 2239.1 kg/$m^3$and 31.53% respectively and it varied from 938 to1189 kg/m^3, 2025 to 2412 kg/$m^3$and 30 to 33% respectively**.** The seed yield was essential for determining the shattering loss of the lathyrus plant**.** The values of all these parameters are depicted in Table 5. Alemayehu, 1997 [1] and Pandey, 1995 [9] also reported similar finding and stated that successful growth of these crops is dependent on soil health.

3.2 Determination of engineering properties of lathyrus crop

The knowledge of engineering properties allows engineers to create lathyrus harvesters that are well-suited for the specific characteristics of the crop.

3.2.2 Bulk density, true density and angle of repose of Lathyrus seeds

The bulk density, true density and angle of repose of lathyrus seeds were found in range of 812-707 kg/m^3, 1288-1150 kg/m^3 and 27.02° to 32° respectively with an average value of 755.9 kg/m^3, 1221.4 kg/m^3 and 29.51°respectively. The SD, CV% and V(P) values are depicted in Table 6.

Table 6: Presentation of bulk density, true density and angle of repose of lathyrus

Description	Bulk density, kg/m^3	True density, kg/m^3	Angle of repose, degree
Mean	755.9	1221.4	29.51
Max	812	1288	32
Min	707	1150	27.02
SD	33.77	47.73	1.661
CV (%)	4.46	3.908	5.630
V (P)	1140.5	2278.7	2.760

3.2.3 Cutting force/rapture force

The force required to cut crop stem was measured with the help of a texture analyzer. The average harvesting moisture content was recorded as 15.28±0.69 % (w.b.) at the time of cutting force measurement and presented in Table 4.4.

Table 7: Rupture force for lathyrus stem

Sample Number	Lathyrus stem	Peak positive force
	Cutting Force kg-sec	kg
1	7.53	7.40
2	6.71	8.06
3	22.6	6.67
4	14.4	8.93
Mean($\bar{x}$)	12.83	7.76
Range	6.71- 22.63	6.67- 8.93
SD (σ)	6.40	0.83
CV (%)	49.91	10.74

The cutting force was measured by cutting one plant stem as mentioned in experimental plan using texture analyzer. The average specific cutting force required to cut one lathyrus plant stem was observed as 13.33N/mm^2.

3.3 General characteristics of lathyrus plant

Table 8 explains about the general characteristics of the plants found in the surveyed areas. It was observed that both are classified on growth habitat as either erect (Prateek) or semi-erect (Mahaterora). On branch arrangement and leaflet shape both have same characteristics, whereas, on pod shape it was reported that Prateek is oblong –elliptical and Mahaterora is medium oblong elliptical. The branches in the plant are evenly distributed from beginning to end of the whole plant. These characteristics will be helping in the designing of the harvester.

Table 8: General characteristics of lathyrus plant

S. No.	Variety →	Prateek		Mahaterora	
	Plant characteristics↓	State	Code	State	Code
1.	Plant growth habitat	Erect	4	Semi erect	3
2.	Branch arrangement	Evenly distributed throughout the whole plant	1	Evenly distributed throughout the whole plant	1
3.	Leaflet shape	Lanceolate	2	Lanceolate	2
4.	Pod shape	Oblong- elliptical	1	Medium oblong elliptical	2

3.4 Energy Requirement of Developed Lathyrus Harvester

Energy required by tractor, implement, human and fuel was calculated as indirect and direct source of energy and total energy required was found to be 872 MJ ha^{-1}.

Table 9: Energy requirement of developed lathyrus harvester

S. No.	Particulars	Value
1	Indirect energy source	
	Total tractor energy, MJ ha^{-1}	34.20
	Total implement energy, MJ ha^{-1}	199.5
	Total energy from indirect energy source	233.7
2	Direct energy source	
	Total human energy, MJ ha $^{-1}$	4.9
	Total fuel energy, MJ ha $^{-1}$	633.4
	Total energy from direct energy source, MJ ha $^{-1}$	638.3
3	Total energy, MJ ha $^{-1}$	872

The energies values calculated with help of formulas mentioned in materials section are presented below in Table 10.

Table 10: Energy requirement of various sources for development of lathyrus harvester

S. No.	Particulars	Value
1.	**Indirect energy source**	
	Energy from tractor	
	Weight of tractor, kg	2630
	Life of tractor, h	10000
	Working hour per hectare	8
	Energy equivalent of tractor, MJ kg $^{-1}$	68.40
	Total tractor energy, MJ ha $^{-1}$	34.20
	Energy from implement	
	Weight of implement, kg	350
	Life of implement, h	300
	Working hour per hectare	8
	Energy equivalent of implement, MJ kg^{-1}	68.40
	Total implement energy, MJ ha^{-1}	199.5
	Total energy from indirect energy source	233.7
2.	**Direct energy source**	
	Human energy	
	Labour requirement	1

	Energy requirement of man, MJ h^{-1}	1.96
	Working hours per hectare	8
	Total human energy, MJ ha^{-1}	4.9
3.	**Fuel energy**	
	Fuel consumption l h^{-1}	4.5
	Working hours per hectare	8
	Energy equivalent of diesel, MJ l^{-1}	56.31
	Total fuel energy, MJ ha^{-1}	633.4
	Total energy from indirect energy source	638.3
	Total energy, MJ ha^{-1}	872

4. Conclusion

The present study provides the basic information about biometric characteristics, engineering properties, crushing resistance of Lathyrus stem along with the energy determination of developed lathyrus harvester. The average (N=50) plant height was 435.8±6.19 mm, with 6.306±1.07 number of branches/plant and average stem diameter was 2.72±0.38 mm. The average plant population/m2, number of pod/plant and number of seeds/pod were 24.8, 18.75±6.19 and 3.91±1.07 respectively.

The average values of true density, bulk density and angle of repose were 755.9 kg/m^3, 1221.4 kg/m^3 and 29.51° respectively. The mean value of rupture force/crushing resistance for lathyrus stem was observed 13.34 N. Also general characteristics of lathyrus plant showed that both the varieties can be suited for mechanical harvesting. The total energy required for developed harvester was 872 MJ ha-1.

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