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Harnessing Fuelwood from *Cajanus cajan* (L.) Millsp.

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Abstract

A two-year field trial on lac production on *Cajanus cajan* (L.) Millsp. was conducted on the research field of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh of India following randomized block design during 2019-20 and 2020-21. After harvest of *C. cajan* seeds and lac as cash crops, the left-over wood of *C. cajan* was evaluated for fuelwood (as an energy stove) for the small and marginal farm households. The mean dry weight of total fuelwood (including shoot+root) varied from 1196.67 to 1393.67 g plant^{-1} in pooled data. The estimated mean weight of total fuelwood (root+shoot) of *C. cajan* varied from 1447.98 to 1686.34 kg ha^{-1} in pooled mean of both the years. The value of total (shoot+root) dry fuelwood per plant varied from ₹ 7,239.85 to ₹ 8,431.70 in pooled mean of both the years. This total fuelwood can fulfill daily household requirement of fuelwood upto 3 years (891 to 1037 days) @ 4.06 kg day^{-1} household^{-1}.

Keywords: Biofuel, fuelwood, fuel, pigeon pea

1. Introduction

C. cajan is one of India's most popular pulse crops (Nene, 2006; Pal et al., 2011; Sarkar et al., 2018; Fuller et al., 2019; Jorrin et al., 2021). In many parts of India, it is an attractive element of subsistence and rainfed farming systems (Saxena et al., 2016; Singh et al., 2016). Since, it is a hardy crop, *C. cajan* can be cultivated successfully either under rainfed or limited input condition (Daniel and Ong, 1990; Singh et al., 2012). The crop provides protein, fodder and fuel wood (Phatak et al., 1993; Zhenghong et al., 1997; Mazur et al., 1998; Egashira and Than, 2006; Odeny, 2007a). *C. cajan* is a perfect choice for small and marginal farmers, particularly in semi-arid dry-land areas (Pandit et al., 2015; Sarkar et al., 2018). It is primarily consumed in India as a split pulse known as 'dal' (Mula and Saxena, 2010). Its immature green seeds and pods are consumed as a green vegetable by tribal people in many States (provinces), including Chattisgarh, Jharkhand, Andhra Pradesh, Karnataka, Gujarat, and the entire North-East Hill region. In the later region, it is primarily grown in kitchen gardens, backyards, hilly tracts and on jhum land (Singh et al., 2016).

The tall and upright *C. cajan* types are well-known for providing fodder and fuel wood to small and marginal farmers (Xuxiao et al., 2001a; Kurt et al., 2017). As *C. cajan* produces strong woody shoots that grow taller and branch profusely, its spindly stems are extensively utilized as a fuel for cooking in energy-short regions of Africa, including Kenya, Malawai and Tanzania, as well as India, Nepal and Sri Lanka (Mula and Saxena, 2010). The stems were also use to make the charcoal that was once used in gunpowder (Kanchan et al., 2013, Sahoo et al. 2021). *C. cajan* is grown in Africa for its woods than its seeds (Mula and Saxena, 2010; Kanchan et al., 2013). Upon harvesting the lac resin, in China *C. cajan* plants are chopped and stored for firewood use in the country's lac growing regions (Chaohong et al., 2001). The crop generates approximately 6 t ha^{-1} of wood fuel (Zhenghong and Fuji, 1997). Fuel wood has been determined to be of exceptional quality, generating energy at a rate of 4,350 kcal kg^{-1} (Yude et al., 1993).

2. Materials and Methods

A two-year field study on *C. cajan* var. TJT-501 was conducted in Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur during the year 2019-20 and 2020-21. *C. cajan* plants were raised in polypropylene bags (PPBs) by following Jawahar model for doubling the income of resource constrained small and marginal farmers. *C. cajan* plants were raised by direct sowing in PPBs filled with 65 kg substrate (40 kg *kapu* i.e., river basin soil+25 kg FYM) enriched with consortium of bio-fertilizers (Table 1). The study was conducted in Randomized Block Design format consisting eight treatments and three replications.

Table 1: Materials used during the experiment

Substrate: Kapu+FYM (40+25 kg polypropylene bag^{-1})
Polyprolyene bag (size: 121×61 cm^2)
Bio-agents: Trichoderma viride, Rhizobium, VAM, PSB, Asperigillus niger
Pigeon pea (TJT-501) seeds
Rangeeni brood lac
Insecticides: Cartap hydrochloride, Emmamectin benzoate
Fungicides: (Dithane M-45)
Knapsack sprayer

Plant to plant and row to row spacing was 6 feet, while the replications were 10 feet apart. The *C. cajan* plants were nipped at 15 days interval till the initiation of flowering. Nipping operation was to induce branching. The foliar application of nutrients was followed as per the treatments (Table 2).

Table 2: Treatment details of the study

No.	Foliar application of	No. of sprays	Spray schedule		
			30 days before BLI	90 days after BLI	30 days after male emergence
T_1	NPK	One	✓	-	-
T_2	Micronutrients	One	✓	-	-
T_3	NPK and micronutrients	One	✓	-	-
T_4	NPK	Two	✓	✓	-
T_5	Micronutrients	Two	✓	✓	-
T_6	NPK and micronutrients	Two	✓	✓	-
T_7	NPK and micronutrients	Three	✓	✓	✓
T_8	Control	No spray			

There were two hand pickings of mature pods from *C. cajan* during both the years in the month of January and April. The *C. cajan* plants were inoculated with brood lac in the month of November for lac production. The lac crop on *C. cajan* matured in the month of June. The plants with mature lac crop were cut from the base. After shade drying, the lac was scrapped from the branches. Thus, after harvesting two cash crops i.e., *C. cajan* seeds and lac, the leftover wood was analyzed for its value.

At the time of harvesting, the plants cut with the help of plant secateurs were marked with permanent markers for recording data and kept in shade for drying. After a week of shade drying, the dry shoots were weighed with the help of digital hanging weighing device (Wei-hang). The roots were also removed from PPBs by emptying it. It was also marked, shade dried and weighed. As the plants were raised in PPBs, complete removal of roots was possible.

The statistical analysis of the research data was performed using Analysis of Variance (ANOVA) tool in MS-Excel of Microsoft office-2007 following Randomized Block Design.

3. Results and Discussion

The pooled mean weight of dry shoot per plant varied from 916.92 g (T_4- Two sprays of NPK) to 1112.50 g (T_6- Two sprays of NPK+micronutrients). The pooled mean dry weight of shoot per plant in T_5, T_6, T_7 and T_8 were significantly higher than T_4. The treatments T_1 (990.50g), T_2 (961.50g), T_3 (942.50 g) and T_4 (916.92 g) were also at par among themselves. The pooled mean weight of dry shoot of T_8 (Control) was higher than that of these four treatments. The pooled mean weight of dry roots per plant^{-1} varied from 240.00 g (T_8- Control) to 308.83 g (T_4- Two sprays of NPK). The latter was followed by T_1 (297.50 g), T_7 (295.83 g), T_2 (287.17 g), T_6 (281.17 g), T_5 (273.33 g) and T_3 (254.17 g). There was no significant difference in the pooled mean weight of roots per plant of *C. cajan* among the treatments. It was more in all the treatments over T_8 (Control). The pooled mean weight of total dry fuelwood (shoot+root) per plant varied from 1196.67 g (T_3- One spray of NPK+micronutrients) to 1393.67 g (T_6- Two sprays of NPK+micronutrients). The treatment T_6 (1393.67 g) and T_7 (1366.67 g) were significantly higher than T_3. The pooled mean weight of total dry fuelwood plant^{-1} of T_8 (Control) was higher than that of T_5, T_1, T_2, T_4 and T_3 (Table 3).

The value of total (shoot + root) dry fuelwood per plant varied from ₹ 5.66 to ₹ 6.65 in 1st year (2019-20), ₹ 6.10 to ₹ 7.29 in 2nd year (2020-21) and ₹ 5.98 to ₹ 6.97 in pooled mean of both the years.

On the basis of mean per plant data under the Jawahar model, the per ha estimated mean weight of dry shoots of *C. cajan* varied from 1109.47 to 1346.13 kg in pooled mean of both the years (Table 4). The estimated mean weight of dry roots of *C. cajan* varied from 290.40 to 359.98 kg ha^{-1} in pooled mean of both the years. The estimated mean weight of total fuelwood (root+shoot) of *C. cajan* varied from 1447.98 to 1686.34 kg ha^{-1} in pooled mean of both the years. This total fuelwood can add to the gross returns of farmers for the overall B:C ratio. The fuelwood yield will save the expenses and daily energy requirement of fuelwood upto 3 years (891 to 1037 days) @ 4.06 kg day^{-1} household^{-1}.

The pooled mean weight of dry shoot per plant varied from 916.92 g (T_4) to 1112.50 g (T_6). The pooled mean dry weight of shoot per plant in T_5, T_6, T_7 and T_8 were significantly higher than T_4. The treatments T_1 (990.50 g), T_2 (961.50 g), T_3 (942.50 g) and T_4 (916.92 g) were also at par among themselves. The pooled mean weight of dry shoot of T_8 (Control) was higher than that of these four treatments.

Table 3: Mean weight of dry fuelwood plant^{-1} of *C. cajan*

Treatments	Mean weight of dry fuelwood per plant (g)		
	Pooled data (2019-20 to 2020-21)		
	Shoot	Root	Total
T_1	990.50 (4.95)	297.50 (1.49)	1288.00 (6.44)
T_2	961.50 (4.81)	287.17 (1.44)	1248.67 (6.24)
T_3	942.50 (4.71)	254.17 (1.27)	1196.67 (5.98)
T_4	916.92 (4.58)	308.83 (1.54)	1225.75 (6.13)
T_5	1018.83 (5.09)	273.33 (1.37)	1292.17 (6.46)
T_6	1112.50 (5.56)	281.17 (1.41)	1393.67 (6.97)
T_7	1070.83 (5.35)	295.83 (1.48)	1366.67 (6.83)
T_8	1082.00 (5.41)	240.00 (1.20)	1322.00 (6.61)
SEm±	34.26	22.80	42.76
CD (p=0.05)	103.93	69.17	129.69

Figures in the parenthesis are values in ₹ @ ₹ 5 kg^{-1} fuelwood

Table 4: Estimated mean weight of dry fuelwood ha^{-1} of *C. cajan*

Treatments	Estimated mean weight of dry fuelwood (kg)		
	Pooled (2019-20 to 2020-21)		
	Shoot	Root	Total
T_1	1198.51 (5992.53)	359.98 (1799.88)	1558.48 (7792.40)
T_2	1163.42 (5817.08)	347.48 (1737.38)	1510.89 (7554.45)
T_3	1140.43 (5702.13)	307.55 (1537.73)	1447.97 (7239.85)
T_4	1109.47 (5547.37)	373.68 (1868.42)	1483.16 (7415.79)
T_5	1232.78 (6163.92)	330.73 (1653.65)	1563.53 (7817.63)
T_6	1346.13 (6730.63)	340.22 (1701.08)	1686.34 (8431.70)
T_7	1295.70 (6478.52)	357.95 (1789.77)	1653.67 (8268.35)
T_8	1309.22 (6546.10)	290.40 (1452.00)	1599.62 (7998.10)

Figures in the parenthesis are values in ₹ ha^{-1} @ ₹ 5 kg^{-1} fuelwood

The dry shoot weight was higher than the dry root weight. However, both serve as good fuelwood for the farmers. Extraction of root from the ground is not only difficult but never complete when compared to that from PPB. Thus, planting of *C. cajan* in PPB is beneficial in many ways, higher plant growth, yield of lac and seeds as well as total fuelwood. In comparison to the dry root weight, the dry shoot weight varied from 196.90 to 295.67% more in different treatments. At the end of the day, small and marginal farmwomen spend more time in collection of fuelwoods daily to cook food for the family. This time and energy can be diverted for other productive work.

If the data is carefully observed, it reveals that plants of treatments T_3 (One spray of NPK+micronutrients) which had higher lac yield had lower total fuelwood yield. This is a matter of interest for both entomologist and economists. The former may like to highlight the influence of phloem feeder on low fuelwood yield. On the contrary, the economist may be excited with the analysis of higher seed yield, lac yield and comparatively higher fuelwood yield from *C. cajan* grown in Jawahar model in contrast to traditional *C. cajan* cultivation.

Fuelwood yield of *C. cajan* varied from 15 to 20 tons ha^{-1} of energy density to the tune of 4000 kcal kg^{-1} (Anonymous, 2013). The fuelwood yield depends on the cultivation practice of *C. cajan*. In the present study, the mean fuelwood yield varied from 1.196 to 1.393 kg per *C. cajan* plant, when it was planted at a spacing of 6×6 ft. Thus with 3025 plants ha^{-1} in Jawahar model, the estimated fuelwood yield is 3.618 to 4.214 tons ha^{-1}; which is equivalent 14,472,000 to 16,856,000 kcal energy. The average rural household requirement of fuelwood in India is 4.06 kg or 16,240 kcal or 79.98 MJ kg^{-1} household^{-1} day^{-1}. It is 2.77 kg day^{-1} in Himalayan tribes (Hussain et al., 2016), 1.9 to 2.2 kg^{-1} household^{-1} day^{-1} in South India (Reddy, 1981), 1.23 kg in Himalayan ranges of Nepal (Mahat et al., 1987), 1.7 to 2.5 kg for southern and south-Asian countries (Dovovan, 1981). The earlier researchers as mentioned above reported average fuelwood consumption of 20–25 kg^{-1} household^{-1} day^{-1}, while in case of Van Gujjar (Himalayin forest tribe), it was 20.09 kg^{-1} household^{-1} day^{-1}. The average fuelwood consumption reported by Awasti et al. (2003) in Garhwal Himalaya was 14.65 kg^{-1} household^{-1} day^{-1}.

Higher content of cellulose, hemicelluloses and lower lignin mass fraction (18.2%) in *C. cajan* fuelwood is reported by Mohan et al. (2006). The presence of high lignocelluloses mass in *C. cajan* fuelwood opens a new area of research for extraction of bio-oil by the process of pyrolysis (Tanquilut et al., 2019; 2020) as they obtained 54% bio-oil yield on dry fuelwood intake. The bio-oil so obtained had a higher H/C ratio, low ash content and higher heating value than the fuelwood of *C. cajan*. The physio-chemical properties of

C. cajan wood reported by Tanquilut et al. (2019) consists of moisture (9.9%), volatile matter (65.9%), Ash (12.3%), fixed carbon (21.8%), heating value (17.1 MJ kg^{-1}), carbon (41.1%), hydrogen (6.2%), nitrogen (0.9%), oxygen (51.9%), cellulose (34.0−34.6%), hemicelluloses (34.2−35.5%) and lignin (17.8−18.2%).

4. Conclusion

India is the largest producer of *C. cajan* in the world with 53.38 lakh ha (64.45%) area (1st rank) and 48.73 lakh tons (57.29%) production (1st rank) with a productivity of 913 kg ha^{-1}, ranking 7th in the world in productivity (DPD, 2017−18). The result of the present study is trying to attract policy makers in India to look for *C. cajan* wood bio-refining of bio-oil as a cheap alternate source of liquid energy for the future.

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