



## Economic effect of mechanical intervention through sub-soiling on growth and yield of rainfed pigeonpea (*Cajanus cajan*)

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### ABSTRACT

A two-year field experiment was conducted to investigate the effect of sub-soiling on plant growth, root morphology and yield of rainfed pigeonpea [*Cajanus cajan* (L.) Millsp.] (Var LRG 41) during 2012-13 and 2013-14. Crop exposed to moisture stress condition from flowering to harvest (120 days) during 2013-14, compared to experiment conducted during 2012-13. The results indicated that sub-soil tillage sustained higher shoot, root growth and seed yield during the year 2013-14, which coincided with end of season drought compared to conventional tillage treatment. Crop growth in terms of plant height, leaf area/plant significantly improved due to sub-soiling compared to conventionally tilled treatment. Similarly sub-soiling recorded significant increase in drought tolerant traits, viz. root length (234%), root dry weight (274%) and relative water content (37%). Consequently, sub-soil tillage recorded significant increase in number of pods/plant by 59%, 100 seed weight by 12% and pod yield by 219% compared to conventionally tilled treatment. Sub-soil tillage proved efficient method of mechanical intervention for drought mitigation under rainfed pigeonpea cultivation.

**Key words:** Morphological attributes, Pigeonpea, Rainfed, Sub-soil tillage, Yield

Sub-soil tillage is one of the most efficient mechanical interventions to break up a plough pan in cultivation. Other beneficiary effects of sub-soil tillage reported by many authors including promoting water storage in the soil (Evans *et al.* 1996), adjusting the proportion of solid, liquid and gas composition of soil (Sidhu and Duiker 2006) improving ecological environment for root development and root activities that enhance the anti-stress capacity of plants (Song *et al.* 2000). The sub-soil can have a large impact on a soil's potential productivity. If this layer of soil is extremely dense, roots may not penetrate, rooting volume will be decreased, nutrient uptake will be reduced, and plants may become susceptible to drought; also, water may not be able to infiltrate into the sub-soil, thus limiting available water for plant growth and increasing surface runoff and potential soil erosion. Disrupting the sub-soil to allow proper water infiltration and root growth may be necessary for optimum plant response (Raper 2013). Jin *et al.* (2007) reported that annual sub-soiling was found effective in

reducing bulk density by 4.9% compared with no till treatments on the sandy loam soils.

The temporal and special variability of climate, especially rainfall, is a major constraint to yield improvement, competitiveness and commercialization of rainfed crops although rainfed areas currently constitute 55% of the net sown area of the country and are home to two-thirds of livestock and 40% of human population. Even after realizing the full irrigation potential, about 50% of the cultivated area will remain rainfed (Anon. 2012). Added to this present cropping systems are over exploited by small sized four-wheeled tractors used for stubble removal, soil preparation, sowing, fertilization, inter cultivation and other operations. Hence effective topsoil depth has gradually decreased and plough pan has thickened (Wang *et al.* 2008). The shallow and compacted topsoil restricts nutrient and water absorption by plants due to poor root growth, hence become susceptible to abiotic stress effects specially drought. Hence there is a need for soil health management not only for top soil but also for sub-soil to break stagnate yield barrier especially in rainfed areas. In this scenario to make effective utilization of rain water in rainfed agriculture through *in-situ* moisture conservation and soil manipulation for soil and nutrient uptake and to minimise erosion (without disturbing top soil) the new and alternative technique was developed and experiments were formulated to study effectiveness.

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The present study was taken up during the years 2012 and 2013 strictly under rainfed conditions to evaluate the impact of sub-soil tillage on growth and yield of pigeonpea [*Cajanus cajan* (L.) Millsp.] and its usefulness for sustainable crop production under rainfed areas.

#### MATERIALS AND METHODS

The experiment was conducted on the dry land farm of Regional Agricultural Research Station, Tirupati, which is situated at an altitude of 182.9 m above mean sea level on 79°E longitude and 13°N latitude. Soils of the experimental fields were sandy loam in texture, low in available nitrogen, medium in phosphorous and potassium and were slightly acidic (pH- 6.4). The field had been under continuous rainfed cultivation of different legume crops and tractor based shallow tillage had been practising regularly. During both years of experiment periods, i.e. 2012-13 and 2013-14, experiments conducted in the same field were used for conducting this investigation.

The experiment was laid out in an independent sample t-test (Student's t-test) with two replicates of each treatment, and each plot was of 100m<sup>2</sup>. Conventional tillage was done using tractor drawn MB plough in the control plot. When the soil was dry, sub-soil tillage was performed with a sub-soiler or chisel plough to a depth of 50 cm and 2 m apart plough lines, before sowing of pigeonpea seeds (Fig 1). The pigeonpea variety LRG 41 was sown on 10-8-2012 during 2012-13 and harvested on 19-2-2013. During the year 2013-14, the crop was sown on 7-8-2013 and harvested on 11-02-2014. During the crop growth period, month wise precipitation was presented in Table 1.

The morphological attributes and drought tolerant traits were recorded on 24.1.2014 (170 days) and yield parameters were recorded at harvest 11-02-14 (188 days) using ten randomly selected and tagged plants in each net



Fig 1 Tilling sub-soil treatment field using sub-soiler

plot and average data is presented. Mean plant height was measured from the ground level to the apex of the main axis and expressed in cm/plant. The mean number of branches/plant was worked out from the same selected ten plants and was expressed as number of branches/plant. Leaf area was recorded by using leaf area meter (LICOR Model 3100) and the average was expressed as leaf area/plant in cm<sup>2</sup>.

The relative water content was recorded as per the procedure of Barrs and Weatherley (1962). For root sampling ten random plants in each treatment were selected and boundaries were defined based on the area occupied by each plant. Roots in the soil layers were carefully removed by digging to a depth of 80 cm (soil was too hard to dig after that) and washed with fresh water to remove adhering soil. Root length was measured using a standard scale from the ground level to the tip of the root. Thus harvested roots were oven dried at 80°C for 48 hr and dry weights were recorded using sensitive electronic balance and expressed in g/plant.

The number of pods from the randomly selected ten plants in each treatment was counted and the average was expressed as number of pods/plant. A lot of seeds were drawn at random from each treatment and weighed. Number of seeds constituting the sample was counted and from these values 100 seed weight was computed. Harvested plants were kept in the field for drying and were removed and weighed (g/plant). It was also calculated for a net plot area and it was computed to hectare and expressed as kg/ha.

#### RESULTS AND DISCUSSION

During the year 2012-13 the rainfall was well distributed throughout the crop duration and significant differences were not observed among all the morphological and drought tolerant traits and yield attributes. Hence the data was not presented (Table 1). However during the year 2013-14, the crop suffered with severe terminal moisture stress from November 2012 (flowering) to February 2013 (harvest) due to failure of north east monsoon. The data on morphological parameters, drought tolerant traits and yield attributes showed significant variability between conventionally tilled plot and sub-soiled plot (Table 2; Fig 2) and detailed results are presented here.

##### *Morphological characters*

Though the plant height is genetically controlled, soil moisture plays critical role in its regulation. Plant height was significantly higher by 47% in sub-soiled treatment compared to conventional tillage treatment during 2013-14, which was concluded by terminal moisture stress. Similarly,

Table 1 Rainfall data during cropping duration in 2012-13 and 2013-14

Month	August	September	October	November	December	January	February
2012-13	166	70.1	204.5	149.2	217		55.2
2013-14	106.7	300.1	194.5	85	0	1	

Table 2 Effect of sub-soil tillage

Character	Treatments	Mean	SD	t-value (p-value)
Plant height (cm)	T0	163.00	7.78	4.387* (0.048)
	T1	239.40	23.36	
No. of branches	T0	8.96	0.79	3.052 (0.093)
	T1	12.53	1.45	
Leaf area (cm <sup>2</sup> )	T0	1866.05	208.50	7.272* (0.018)
	T1	7186.25	1013.38	
Relative water content (RWC) (%)	T0	40.72	2.66	4.156* (0.043)
	T1	55.72	4.36	
Root dry weight (g)	T0	63.05	7.85	5.573* (0.031)
	T1	235.60	43.08	
Root length (cm)	T0	23.97	5.00	10.787* (0.008)
	T1	80.03	5.39	
No. of pod/plant	T0	146.84	8.43	9.771* (0.010)
	T1	234.03	9.39	
100 seed weight (g)	T0	13.48	0.04	8.310* (0.014)
	T1	15.15	0.28	
Pod yield (kg/ha)	T0	114.10	7.50	26.399* (0.001)
	T1	364.26	11.11	

T0: Mould board ploughing; T1: Sub soil tillage followed by mould board ploughing; \*Significant at P = 0.05

the leaf area/plant which is an active photosynthetic surface and prime source to feed sink was significantly higher by 285% in sub-soil tillage treatment compared to control plots (Fig 2). However number of branches recorded non significant increase in sub-soiled plot. These results clearly demonstrate the magnitude of response of sub-soil tillage treatment in sustaining plant growth and leaf area by maintaining higher tissue water status. Whereas in conventional tilled treatment, plants shred leaves and restricted its growth due to poor tissue water status. Similar results of increased biomass (26.7%) due to sub-soil tillage was reported in maize compared to conventional tillage (Hongguangcai *et al.* 2104)

#### Drought tolerant traits

Maintenance of plant water status is more important



Fig 2 Crop growth differences in sub-soil and conventionally tilled plots

for cellular functions, which is a prerequisite for any crop to perform under drought. Relative water content (RWC) is one of the reliable measures to quantify plant water status. Sub-soil tillage treatment maintained significantly higher (37%) RWC compared to conventional tillage especially during 2013-14, where crop suffered with moisture stress from flowering to pod maturity. Rekika *et al.* (2000) reported that enhanced RWC under moisture stress conditions helped the plants to perform the physiological processes like stomatal conductance, photosynthesis, biochemical metabolism to continue more effectively.

Root system plays an important role under drought conditions. The nature and extent of root traits, viz. root length and root dry weights are considered to be major factors affecting plant response to water stress. Soil tillage treatment recorded significantly higher root length (234%) and root dry weight (274%) compared to conventional tillage treatment (Table 2). It implies that due to the breaking of plough pan through sub-soiler, plants extended root system to deeper layers and maintained water uptake and plant water balance under moisture stress conditions. Hence the plants could maintain higher plant growth, green leaf area and thus maintained higher morphological and physiological activities.

#### Yield and its attributes

Yield is a complex polygenic trait which is highly influenced by the environment. The stress factors especially drought affect plant growth and development and causes a sharp decrease of plant productivity (Sudhakar *et al.* 2006). In the present investigation also number of pods/plant, 100 seed weight and pod yields of pigeonpea were affected in conventionally tilled plot, which was affected due to moisture stress. However such negative effect was counteracted with the mechanical intervention of tillage with sub-soiling up to 50 cm.

From the data, it is clearly evident that sub-soiling was responsible for significant increase in number of pods/plant by 59%, 100 seed weight by 12% and pod yield by 219% compared to conventionally tilled treatment. Such yield advantage due to sub-soiling can be ascertained to enhanced soil water storage capacity due to breakup of plough pan and their by entry of rain water into the deeper layers of field. It may also be due to reduction in bulk density at root zone. Improved water uptake by plants in sub-soil treatment owing to increased depth of the sub-soil tillage, promoted root penetration. Thus soil-plant interaction was altered in spite of soil moisture stress and improved drought tolerance in terms of improved plant water relations, sustained biochemical process and resulted in significantly higher pod yields. It is important to note that such beneficiary effect due to sub-soiling was proliferated specially where crop exposed to moisture stress condition during 2013-14 compared to crop season 2012-13. The present investigation exhibits advantages of sub-soil tillage for crops grown under rainfed condition and can be used as a potential option for drought mitigation.

It was concluded that Sub-soil tillage sustained higher shoot, root growth and seed yield during the year 2013-14 compared to conventional tillage treatment. Crop growth in terms of plant height, leaf area/plant significantly improved due to sub-soiling compared to conventionally tilled treatment. Sub-soiling recorded significant increase in drought tolerant traits, viz. root length (234%), root dry weight (274%) and relative water content (37%). Sub-soil tillage also recorded significant increase in number of pods/plant by 59%, 100 seed weight by 12% and pod yield by 219% compared to conventionally tilled treatment. Sub-soil tillage proved efficient method of mechanical intervention for drought mitigation under rainfed pigeonpea cultivation.

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