__Original Research Article__

Conservation Agriculture Strategies Evaluation Under Rainfed Conditions

ABSTRACT

Continuous tillage has a significant impact on the characteristics of the soil; therefore, it's critical to use tillage techniques that preserve crop production, prevent soil structure from being destroyed, and provide greater financial returns rather than harming the health of the soil. Practicing agriculture through minimum soil disturbance, incorporation of crop residues through insitu green manuring enhances the crop growth attributes of pigeonpea under thirsty and nutrient hunger dryland conditions by improving the physicochemical and biological properties of soil. A field investigationwas carried out to evaluate conservation agriculture effect on agronomic growth attributes of pigeonpea and set up in spilt plot design. Among all the tillage practices conventional tillage with horsegraminsitu green manuring has recorded maximum plant height, leaves ,branches,stem girth at all growth stages and yield attributes. However, M_1witnessed lower benefit to cost ratio than reduced tillage (M_2) (1 Harrowing + 1 intercultural operation + pre-emergence herbicide). Farming with zero tillage alone affects the plant growth by excessive weed growth, soil compaction and which results in minimum yield. Therefore optimum number of tillage operations is the key to maintain soil health and to achieve the best benefit for the rupee invested.

Keywords: Conservation tillage, Green manuring, Stem girth, Chlorophyl, yield per plant, Rain Water Use Efficiency.

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1. Introduction

Pigeonpea (Cajanus cajan) is one of the most important pulse crops in Indiaand commonly known as redgram or arhar. Pigeonpea being, excellent source of high-quality protein and carbohydrate, it occupies an important place in vegetarian population. Flower drop is a big problem in pigeonpea and it is the main reason of lower productivity of pigeonpea.The Indian economy is built on agriculture, which is primarily rainfed in the country. Rainfed agriculture is a major factor in the global food security equation. About 85 million hectares (m ha) of India's land are used for rainfed agriculture, making up 60% of the nation's net cultivated area and providing food for 40% of its people.

Due to moisture stress during crucial periods of crop growth, the unpredictable and uneven distribution of rainfall and water loss through runoff cause low and unstable crop yield (Pundik and Tathod, 2019). Therefore, in situ green manuring and tillage improve crop yield, but in situ green manuring and other mechanical soil manipulation techniques are necessary for sustained crop production in rain-fed agriculture.Tillage improves the soil's ability to support plant development. Continuous soil tillage has a significant impact on the qualities of the soil, so it's critical to use tillage techniques that prevent soil structure degradation and preserve crop production.Numerous changes associated with intensive agriculture, such as excessive land tilling, water and fertilizer applications, as well as the risk of environmental pollution and degradation of soil and water resources, are blamed for India's massive attempt to increase agricultural production. It has recently been determined that high levels of soil disturbance from tillage operations are not necessary to get high crop yields (Saha et al., 2010). According to Lumpkin and Sayre (2009), conservation agriculture (CA) is a method of farming that involves minimizing soil disturbance, using agricultural wastes, and using appropriate crop rotations. Numerous cultural methods, like direct sowing, direct drilling, and zero tillage, meet the CA definition. Researchers have been paying close attention to conservation agriculture (CA) since it offers numerous environmental advantages as well as the ability to increase production, efficiency in the use of resources, and soil health (Sepat et al., 2015). Minimum mechanical soil disturbance, organic mulch cover and crop diversification constitute the major practices under CA.

Tillage systems influence physical, chemical, and biological properties of soils and have a major impact on soil productivity and sustainability. However, impact of a particular tillage system on soil properties depends on the site (Hati, 2014). FAO (2007) defined the CA as ‘resource saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while conserving the environment. Tillage plays an important role in controlling weeds and managing crop residues, but the primary purpose of tillage is to change soil structure. Soil structure is changed to create conditions favouring germination of seeds, emergence of seedlings and growth of cultivated plants (Carman, 1997).

Growing numbers of growers are incorporating conservation tillage as a popular tool into their production plans. In addition to reducing soil erosion, conservation tillage can encourage input conservation by using less tillage equipment. Because of the reduced tillage,

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there is less need for labor, less fuel is used, longer machinery life is encouraged, and lower horsepower tools can be used. Nevertheless, higher chemical weed control expenses may somewhat outweigh these advantages (Kumar et al., 2015).Soil moisture conservation is a critical issue in rainfed farming whereas conservation tillage management systems (zero-tillage and minimum tillage) are effective means in reducing water loss from the soil and improving soil moisture regime in dry land agriculture system which ultimately improved the growth attributes of the pigeonpea. In the mostly sub-tropical and tropical environment existing in the Indian sub-continent, where lands are mostly at the verge of degradation with deteriorated soil quality, the studies that warranted a shift of CT to the reduced or minimum tillage are highly relevant for future. However, such studies should be conducted on long-term basis using appropriate reduced tillage levels. The results of our study are not only useful to the given location under semi-arid Alfisols, but could also work as an analogy for developing a similar relationship for other crops in different rainfed tropics across the world. The beneficial effects of reduced tillage could be accrued more effectively, if adequate amount of crop residue is retained on the soil surface on a long-term basis (Ramachandrappa et al., 2017). The field investigation was carried out to evaluate the influence of conservation agriculture on growth and economics of pigeonpea.

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2. Material and methods

2.1 Experimental site location and treatment details

A field experiment was conducted at Dryland farm, AICRP on dryland agriculture, UAS, GKVK, Bangalore (13^{o} 05' N latitude and 77^{0} 34' E longitude) at an altitude 294 m above mean sea level during kharif 2021 on sandy loam soil.The actual rainfall received during the year 2021 was 1328.4 mm as against the normal rainfall of 954.7 mm which is excess (373.7 mm) than the normal rainfall. Treatment consisting of three conservation tillage practices on main plot and each of which has three sublots of in-situ green manuring practices laid out in split plot design with three replications,Conventional tillageM_1: (1 Ploughing + 2 Harrowing + 1 Intercultural operation), Reduced tillage M_2 : (1 Harrowing + 1 intercultural operation + pre-emergence herbicide), Zero tillage (M_3): (Pre-emergence herbicide) and sub plots of *in-situ* green manuring practices, C_1: Control, C_2:Sunhemp green manuring, C_3:Horsegram green manuring.Pendimethalin 30 per cent emulsifying concentration @ 1000 g active ingredient per hacterwas applied in treatments M_2 andM_3 plots after two days of sowing using Knapsack sprayer fitted with a WFN 78 nozzle and a spray volume of 750 L ha^{-1}. TheHorsegram and Sunhemp green manuring crops are grown in the month of april and their residue at 50 percent of flowering was used as in-situ green manuring followed by sole pigeonpea sowing in the month of may. The main crop pigeonpea was harvested in the month of Novemer. Before harvesting, growth traits at 30 days period was observed and yield parameters were observed from fully developed pods of five randomly selected tagged plants.For each of five randomly selected tagged plants in each treatment, the plant height expressed in centimeterfrom ground level to the growing tip of the plant, total number of fully opened trifoliate leaves and the number of total branches emergingwere noted, Stem girthexpressed in millimetres were measured at 15cm above the ground level using digital vernier calliper, the mean chlorophyll content of green leaves at bottom, middle and tip of each pant expressed in percentage was measured using chlorophyll meter (Model, SPAD - 502), two plants were selected randomly from a destructive sampling area were uprooted and different plant parts *viz.*, leaf, stem, root and reproductive parts were separated. The samples were first air dried and then oven dried to aconstant weight at 70 ^{0}C in hot air oven and their dry weight was recorded. The oven dry weight of leaf and stem were recorded at all the stages while, the reproductive part dry weight was recorded at 120, 150, 180 DAS and at harvest. Mean of two plants dry matter accumulated in all the parts of crop was obtained as total dry matter per plant.Whereas, the number of fully developed pods were counted manuallyandthreshed, sun dried to 10-12 % moisture content toestimate per plant yield and test weight of 100 seed (g) was also worked.

2.2. Rainwater use efficiency

Rainwater use efficiencywas calculated according to Oweis (1997) by,

$$\text{RWUE (kg ha-mm}^{-1}\text{)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Rain water used (mm)}} \quad (1)$$

The cost of cultivation, gross returns, net returns per hectare, and the benefit to cost ratio (B:C) were determined by taking into account the pricing of the outputs in the active local markets as well as the cost of the various inputs used. Its specifics are provided in

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Appendix 1. Gross returns were determined using the price of pigeonpea grain yield and stalk that was in effect on the market at the time of harvest.

Net return (₹ ha^{-1}) = Gross return – Total cost of cultivation(2)

$$\text{B:C ratio} = \frac{\text{Gross return(Rsha}^{-1}\text{)}}{\text{Cost of cultivation(Rsha}^{-1}\text{)}} \quad (3)$$

3.0 Results and Discussion

3.1 Plant height and number of leaves per plant

Table 1 displays the information regarding the height of the plants and the number of leaves on each plant. The pigeionpea crop's plant height and leaf count have significantly varied due to various conservation tillage techniques and in-situ green manuring crops. Among different conservation tillage practices the conventional tillage (M_1) has recorded maximum plant height and number of leaves per plant (75.77 , 116.63, 184.10, 192.15, 195.60 , 201.65 cm, and 31.59, 77.70, 287.44, 314.78, 209.97, 184.64, respectively at 60, 90, 120, 150, 180 DAS, at harvest, respectively) as compared to lowest in zero tillage (M_3) (66.90, 102.50, 167.47, 175.13, 179.86, 182.60 cm and 25.42, 63.22, 218.82, 271.27, 180.87, 154.60 respectively).Whereas, the results of reduced tillage (M_2) (72.41, 114.39, 179.71, 191.31, 193.38, 197.01 cm and 28.55, 74.12, 260.54, 302.84, 195.61, 161.49, respectively) are on par with the conventional tillage at all growth stages of pigeon pea. The highest plant height and number of leaves in conventional tillage may be attributed to plowing, harrowing the soil before planting, and creating a loose, friable soil texture that allowed for better soil aeration and improved seed germination. Subsequent intercultural operations also assisted in the proper establishment of the entire crop stand. Additionally, increased rainfall and improved pulverization from tillage operations allowed more water to penetrate the soil, allowing crop roots to grow into deeper layers and absorb moisture from lower depths. These results are in conformity with the findings of Vijaymahantesh*et al*. (2013); Malviya *et al.* (2019).

Among the *in-situ* green manuring crops, horsegram (C_3) has recorded significantly maximum with respect to plant height and number of leaves per plant (76.68, 117.59, 184.27,

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193.48, 197.70, 201.84 cm and 31.50, 83.48, 281.64, 318.52, 213.41, 184.69, respectively at 60, 90, 120, 150, 180, at harvest, respectively) as compared to control (C1) (67.55, 103.80, 168.75, 178.71, 181.36, 184.70 cm and 25.23, 61.49, 225.20, 271.33, 172.10, 148.82, respectively). Whereas, *in-situ* green manuring of horsegram with respect to plant height at all growth intervals and number of leaves per plant except in 60 DAS was on par with *in-situ* green manuring of sunhemp (C_2). The interaction effect between the various conservation tillage and *in-situ* green manuring practices were found non - significant. However, maximum plant height and number of leaves per plant was recorded in the interaction combination of M_1C_3(Conventional tillage + Horsegram) (80.87, 125.39, 193.43, 199.52, 203.02, 207.82 cm and 34.72, 90.40, 318.65, 339.14, 234.62, 210.80, respectively at 60, 90, 120, 150, 180, at harvest, respectively) and lowest were recorded in the interaction of M_3C_1 (zero tillage + control). The maximum plant height and number of leavesplant^{-1} in C_3 (Horsegram*in-situ* green manuring) may be due to lower bulk density, higher infiltration rate, higher moisture content witnessed in the dry spell period and higher nutrients uptake. These results are in line with the results of Patil *et al.* (2009); Timalsina*et al.,* (2021) and Mallareddy *et al.* (2015).

Table 1: Plant height and Number of leaves plant^{-1}, as influenced by conservation tillage system and *in-situ* green manuring in pigeonpea cropping system

Treatments	Plant height (cm)						Number of leaves plant^{-1}					
	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	at harvest	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	at harvest
Tillage practice												
M_1: Conventional tillage	75.77	116.63	184.10	192.15	195.60	201.65	31.59	77.70	287.44	314.78	209.97	184.64
M_2: Reduced tillage	72.41	114.39	179.71	191.31	193.38	197.01	28.55	74.12	260.54	302.84	195.61	161.49
M_3: Zero tillage	66.90	102.50	167.47	175.13	179.86	182.60	25.42	63.22	218.82	271.27	180.87	154.60
S. Em. ±	**1.69**	**2.83**	**3.23**	**3.34**	**3.01**	**3.76**	**1.16**	**2.85**	**12.13**	**8.31**	**5.33**	**5.96**
CD (p=0.05)	**6.64**	**11.10**	**12.70**	**13.11**	**11.80**	**14.75**	**4.54**	**11.19**	**47.62**	**32.65**	**20.93**	**23.39**
***In-situ* green manuring crops**												
C_1: Control	67.55	103.80	168.75	178.71	181.36	184.70	25.23	61.49	225.20	271.33	172.10	148.82
C_2: Sunhemp	70.85	112.14	178.26	186.39	189.78	194.72	28.82	70.07	259.96	299.05	200.94	167.22
C_3: Horsegram	76.68	117.59	184.27	193.48	197.70	201.84	31.50	83.48	281.64	318.52	213.41	184.69
S. Em. ±	**2.26**	**3.43**	**2.83**	**2.95**	**3.99**	**3.23**	**0.61**	**5.49**	**12.37**	**10.47**	**8.89**	**8.86**
CD (p=0.05)	**6.98**	**10.57**	**8.72**	**9.08**	**12.29**	**9.95**	**1.88**	**16.91**	**38.12**	**32.26**	**27.39**	**27.31**
Interaction												
M_1C_1	71.50	107.73	171.29	182.13	187.15	193.76	27.42	68.08	256.64	291.54	181.27	162.60
M_1C_2	74.93	116.77	187.57	194.80	196.63	203.38	32.61	74.62	287.01	313.67	214.02	180.53
M_1C_3	80.87	125.39	193.43	199.52	203.02	207.82	34.72	90.40	318.65	339.14	234.62	210.80
M_2C_1	69.63	105.85	172.34	187.44	187.69	189.43	26.04	64.42	227.92	278.08	172.00	141.80
$M2C_2$	71.75	117.12	179.29	191.31	192.59	197.31	28.30	74.86	271.98	310.57	203.33	167.93
M_2C_3	75.85	120.21	187.52	195.18	199.85	204.29	31.30	83.10	281.72	319.88	211.49	174.73
M_3C_1	61.51	97.82	162.63	166.58	169.22	170.90	22.22	51.99	191.03	244.37	163.03	142.06
M_3C_2	65.88	102.53	167.92	173.07	180.13	183.47	25.55	60.73	220.90	272.92	185.48	153.20
M_3C_3	73.32	107.16	171.87	185.74	190.23	193.42	28.49	76.94	244.54	296.54	194.11	168.53
S. Em. ±	**3.92**	**5.94**	**4.90**	**5.11**	**6.91**	**5.60**	**1.06**	**9.50**	**21.43**	**18.13**	**15.40**	**15.35**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

3.2 Number of branches plant^{-1} and plant stem girth

The data pertaining to number of branches plant^{-1} and plant girth is presented in Table 2. The different conservation tillage practices and *in-situ* green manuring crops have caused significant variation on number of branches per plant and plant stem girth of the pigeionpea crop. Among different conservation tillage practices the conventional tillage has recorded

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significantly maximum number of branches per plant and plant stem girth (3.37, 7.41, 30.00, 33.84, 35.27, 35.72 and 6.12, 10.62, 16.72, 17.82, 18.24, 18.37 mm, respectively at 60, 90, 120, 150, 180 DAS, at harvest, respectively) as compared to zero tillage (2.74, 5.61, 23.29, 26.33, 28.31, 29.35 and 5.55, 9.16, 14.38,14.89, 15.30, 15.77 mm, respectively).The highest plant stem girth may be due to the improved photosynthetic caused accumulation of more dry matter in plant parts and it is clearly evident from the results of total dry matter production of the study. These results are in support by the findings of Aikins *et al.* (2012); Mathukia*et al*. (2015); Oke*et al.* (2019) andUmoh *et al.* (2021).

Among the *in-situ* green manuring crops, horsegram (C_3) has witnessed significantly maximum number of branches plant^{-1} and plant stem girth of (3.35, 7.45, 30.15, 34.34, 36.27, 37.04 and 6.19, 10.69, 16.70, 17.67, 18.33,18.48 mm, respectively at 60, 90, 120, 150, 180, at harvest, respectively) as compared to their respective control (C_1) (2.61, 5.36, 22.75, 25.95, 27.51, 28.22 and 5.26, 8.71, 13.95, 14.36, 14.72, 14.94 mm, respectively). The interaction effect between the various conservation tillage and *in-situ* green manuring practices was found non - significant.However, numerically maximum number of branches per plant and plant stem girth was recorded in the interaction combination of M_1C_3 (Conventional tillage + horsegram)(3.71, 8.35, 33.76, 37.69, 38.93, 39.04 and 6.54, 11.71, 17.70, 19.38, 19.92, 20.06 mm, respectively)and lowest were recorded in the interaction of M_3C_1 (Zero tillage + control). The highest number of branches and stem girth in C_3 (Horsegram*in-situ* green manuring) may be due to enhance photosynthetic caused the improved growth of the plant and resulted to form more branches. The plant branches and stem girth increased with days after sowing of crop due to increased plant height resulted in the accumulation more dry matter in the stem and otherparts of plant. These results are in line with the results of Mallareddy *et al*. (2015) and Meena *et al*. 2015.

Table 2: Number of branches per plant and Girth 15 cm above the ground as influenced by conservation tillage system and *in-situ* green manuring in pigeonpea cropping system

Treatments	Number of Branches (per plant)						Stem Girth mm (15 cm above the Ground)					
	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	At harvest	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	At harvest
Tillage practice												
M_1: Conventional tillage	3.37	7.41	30.00	33.84	35.27	35.72	6.12	10.62	16.72	17.82	18.24	18.37
M_2: Reduced tillage	2.99	6.19	25.76	29.97	31.33	32.42	5.76	9.89	15.54	16.21	16.75	16.78
M_3: Zero tillage	2.74	5.61	23.29	26.33	28.31	29.35	5.55	9.16	14.38	14.89	15.30	15.77
S. Em. ±	**0.11**	**0.31**	**1.26**	**1.36**	**0.88**	**0.73**	**0.11**	**0.24**	**0.40**	**0.56**	**0.56**	**0.49**
CD (p=0.05)	**0.44**	**1.22**	**4.95**	**5.34**	**3.44**	**2.85**	**0.43**	**0.94**	**1.56**	**2.18**	**2.19**	**1.93**

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***In-situ* green manuring crops**												
C_1: Control	2.61	5.36	22.75	25.95	27.51	28.22	5.26	8.71	13.95	14.36	14.72	14.94
C_2: Sunhemp	3.14	6.39	26.15	29.85	31.13	32.23	5.97	10.27	15.99	16.89	17.25	17.49
C_3: Horsegram	3.35	7.45	30.15	34.34	36.27	37.04	6.19	10.69	16.70	17.67	18.33	18.48
S. Em. ±	**0.18**	**0.20**	**1.25**	**1.12**	**1.88**	**1.19**	**0.14**	**0.26**	**0.45**	**0.38**	**0.42**	**0.36**
CD (p=0.05)	**0.54**	**0.62**	**3.85**	**3.44**	**5.78**	**3.67**	**0.42**	**0.81**	**1.37**	**1.17**	**1.29**	**1.12**
Interaction												
M_1C_1	3.05	6.04	24.99	28.71	30.60	30.72	5.59	9.09	15.57	15.68	16.04	16.14
M_1C_2	3.36	7.82	31.26	35.13	36.27	37.40	6.23	11.05	16.89	18.41	18.77	18.90
M_1C_3	3.71	8.35	33.76	37.69	38.93	39.04	6.54	11.71	17.70	19.38	19.92	20.06
M_2C_1	2.57	5.38	22.78	25.92	27.27	28.35	5.21	8.71	14.31	14.57	14.93	14.96
$M2C_2$	3.19	6.10	25.58	28.59	29.67	30.73	5.98	10.31	15.96	16.85	17.21	17.23
M_2C_3	3.21	7.09	28.91	35.41	37.07	38.18	6.10	10.66	16.34	17.22	18.12	18.15
M_3C_1	2.22	4.66	20.48	23.23	24.67	25.60	4.99	8.34	11.96	12.83	13.19	13.72
M_3C_2	2.88	5.25	21.61	25.84	27.47	28.54	5.70	9.44	15.11	15.42	15.78	16.36
M_3C_3	3.13	6.91	27.78	29.92	32.80	33.90	5.94	9.71	16.06	16.41	16.95	17.24
S. Em. ±	**0.30**	**0.35**	**2.16**	**1.94**	**3.25**	**2.06**	**0.23**	**0.46**	**0.77**	**0.66**	**0.72**	**0.63**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

3.3 Chlorophyll content and total dry matter production

The data pertaining to Soil Plant Analysis Development (SPAD) and total dry matter production per plant is presented in Table 3.The measurement of SPAD is an indicative of greenness of the plant, indirectly representing chlorophyll content of plant. Different conservation tillage practices and *in-situ* green manuring crops have caused significant variation on chlorophyll content and total dry matter production per plant of the pigeionpea crop. Among different conservation tillage practices the conventional tillage (M_1) has recorded significantly maximum chlorophyll content and total dry matter production plant^{-1}(41.24, 43.37, 54.25, 48.49, 42.71, 37.83 and 14.31, 46.62, 82.34 ,162.42, 205.61, 232.33 g plant^{-1}, respectively at 60 , 90 , 120, 150, 180, at harvest, respectively) as compared to zero tillage (M_3) (37.73, 39.67, 48.92, 42.63, 37.61, 33.94 and 12.01, 41.05, 76.46, 150.76, 189.29, 212.97 g plant^{-1}, respectively) and which was on par with the reduced tillage with respect to chlorophyll at all growth intervals and total dry matter production except in 60 DAS (38.72, 41.63, 50.42, 46.24, 40.65, 36.70 and 13.19, 44.66, 79.41, 158.83, 196.73, 225.73 g plant^{-1}, respectively).The favourable soil physical condition due to optimum tillage practices promoted the root growth and enhanced the uptake of water and nutrients has increased plant chlorophyll content and plant total biomass growth through increased plant height, number of branches andleaves thereby increasing the SPAD Value. These reults are conformity with the findings of Wasnik *et al.* (2022);Malviya *et al.* (2019); Meena *et al.* (2015); Jan buczek*et al*. (2021); Khaemba *et al.* (2016) and Rajesh *et al*. (2015).

Among the *in-situ* green manuring crops, the horsegram (C_3) has witnessed significantly maximum chlorophyll content and total dry matter production per plant of (41.40, 44.11, 53.37, 48.69, 41.48, 38.31, and 13.82, 48.32, 83.45, 163.53, 206.53, 232.24 g

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plant^{-1} , respectively at 60, 90, 120, 150, 180 DAS, at harvest, respectively) as compared to their respective control (C_1) (36.65, 38.80, 48.62, 43.42, 39.37, 34.07 and 12.38, 39.96, 74.96, 152.87, 188.02, 216.34 g plant^{-1}, respectively at 60, 90, 120, 150, 180 DAS, at harvest, respectively).The chlorophyll content and total dry matter production trend observed among the *in-situ* green manuring crops was in the order of $C_3 > C_2 > C_1$. The interaction effect between the various conservation tillage and *in-situ* green manuring practices have not significantly influenced thechlorophyll content and total dry matter production per plant at all the growth stages of the crop. However, numerically maximum chlorophyll content and total dry matter production plant^{-1} was recorded in the interaction combination of M_1C_3 (conventional tillage + horsegram) (44.07, 47.03, 57.07, 51.56, 44.12, 40.54 and 14.99, 51.52, 86.90, 169.00, 214.66, 242.00 g plant^{-1}, respectively at 60, 90, 120, 150, 180 DAS, at harvest, respectively) and lowest was in M_3C_1 (zero tillage + control, table 3). The balanced nutrient and reduced moisture stress in plant with continues availability of soil moisture helps to more chlorophyll development in crop plant which helped in production of higher plant dry matter. Malik *et al*. (2011);Meena *et al.* (2015); Khaemba *et al.* (2016); Nagaraj *et al.*(2019) and Honnali*et al.* (2020).

Table 3: Chlorophyll content and Total dry matter as influenced by conservation tillage system and *in-situ* green manuring in pigeonpea cropping system

Treatments	**Chlorophyll content (Spad value)**						**Total dry matter (g plant^{-1})**					
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**180 DAS**	**At harvest**	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**180 DAS**	**At harvest**
Tillage practices												
M_1: Conventional tillage	41.24	43.37	54.25	48.49	42.71	37.83	14.31	46.62	82.34	162.42	205.61	232.33
M_2: Reduced tillage	38.72	41.63	50.42	46.24	40.65	36.70	13.19	44.66	79.41	158.83	196.73	225.73
M_3: Zero tillage	37.73	39.67	48.92	42.63	37.61	33.94	12.01	41.05	76.46	150.76	189.29	212.97
S. Em. ±	**0.68**	**0.70**	**1.04**	**1.10**	**0.97**	**0.72**	**0.23**	**0.82**	**1.08**	**2.22**	**2.88**	**3.15**
CD (p=0.05)	**2.68**	**2.75**	**4.08**	**4.32**	**3.81**	**2.83**	**0.89**	**3.23**	**4.24**	**8.71**	**11.30**	**12.39**
***In-situ* green manuring crops**												
C_2: Control	36.65	38.80	48.62	43.42	39.37	34.07	12.38	39.96	74.96	152.87	188.02	216.34
C_2: sunhemp	39.63	41.75	51.60	45.25	40.11	36.10	13.32	44.06	79.80	155.61	197.09	222.44
C_3: Horsegram	41.40	44.11	53.37	48.69	41.48	38.31	13.82	48.32	83.45	163.53	206.53	232.24
S. Em. ±	**0.92**	**1.15**	**0.92**	**0.76**	**0.52**	**0.77**	**0.23**	**1.21**	**1.90**	**1.64**	**3.23**	**4.02**
CD (p=0.05)	**2.82**	**3.55**	**2.84**	**2.35**	**1.61**	**2.36**	**0.70**	**3.72**	**5.85**	**5.05**	**9.95**	**12.38**
Interaction												
M_1C_1	38.56	40.03	51.58	45.92	41.62	34.77	13.72	41.33	76.33	157.10	196.06	223.33
M_1C_2	41.08	43.04	54.09	47.97	42.39	38.19	14.22	47.02	83.78	161.16	206.11	231.65
M_1C_3	44.07	47.03	57.07	51.56	44.12	40.54	14.99	51.52	86.90	169.00	214.66	242.00
M_2C_1	37.01	38.95	48.70	43.41	39.82	35.53	12.36	40.87	75.87	153.33	185.65	216.00
M2C_2	39.04	41.87	50.74	46.48	40.46	36.44	13.41	44.67	78.91	155.57	196.61	223.58
M_2C_3	40.11	44.06	51.81	48.84	41.67	38.13	13.79	48.45	83.45	167.60	207.92	237.60
M_3C_1	34.39	37.41	45.58	40.91	36.68	31.92	11.05	37.67	72.67	148.19	182.33	209.70
M_3C_2	38.78	40.35	49.97	41.31	37.49	33.66	12.33	40.48	76.72	150.10	188.54	212.08
M_3C_3	40.02	41.24	51.21	45.65	38.66	36.26	12.67	45.00	80.00	154.00	197.00	217.13
S. Em. ±	**1.59**	**1.99**	**1.60**	**1.32**	**0.90**	**1.33**	**0.40**	**2.09**	**3.29**	**2.84**	**5.59**	**6.96**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

3.4 Grain yield and yield parameters

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The data pertaining to grain yield, stalk yield, yield plant^{-1}, number of pods plant^{-1} and test weight is presented in Table4.Conventional tillage (M_1) had found with significantly higher grain yield, stalk yield, yield plant^{-1}, number of pods plant^{-1} and test weight of pigeonpea (974 kg ha^{-1}, 3788 kg ha^{-1}, 52.07g, 105.42, and 13.10 g, respectively) followed by reduced tillage (M_2) (941 kg ha^{-1}, 3561 kg ha^{-1}, 50.90 g, 104.27, and 13.08 g, respectively) as compared to zero tillage (M3) (813 kg ha^{-1}, 3425 kg ha^{-1}, 45.78 g, 94.31 and 12.38 g, respectively). Among the different tillage practices the higher grain yield under conventional tillage has led to significantly higher rain water use efficiency (0.82 kg ha-mm^{-1}) as compared to minimum tillage (0.79 kg ha-mm^{-1}) and zero tillage (0.68 kg ha-mm^{-1}). This higher rain water use efficiency under conventional tillage indicates more kg of grain produced per unit mm of water used. The higher grain yield in the conventional tillage was attributed to significantly higher yield parameters viz., number of pods, yield per plant and test weight. The higher yield and yield parameters in conventional tillage were due to ploughing and harrowing operations, sequence intercultural operations caused lower bulk density, higher infiltration, higher nutrient availability to plant and better control of weeds resulted in better plant height, number of leaves, total number of branches,plant girth, chlorophyll content, and total dry matter production. These results are in conformity with the findings of Saha *et al*. (2010) who realized significantly higher yield of both maize and mustard with conventional tillage (2.93 and 1.83 t ha^{-1}, respectively) as compared to zero tillage (2.08 and 1.59 t ha^{-1}, respectively); Rajesh *et al*. (2015); Jin *et al.* (2009); Prasad *et al.* (2016); Singh and Singh (2008); Rashidi *et al.* (2008) and Vijayamahantesh*et al*. (2013) who recorded the highest growth and yield parameters in the conventional tillage followed by reduced tillage and over by the zero tillage.

Among the *in-situ* green manuring crops the horsegram (C_3) has witnessed significantly maximum grain yield, stalk yield, yield plant^{-1}, number of pods plant^{-1} and test weight (1054kg ha^{-1}, 3770 kg ha^{-1}, 56.85 g, 112.54 and 13.62 g, respectively) followed by sunhemp (C_2) *in-situ* green manuring (921 kg ha^{-1}, 3554 kg ha^{-1}, 49.83 g, 101.25 and 12.98 g, respectively) as compared to control (C_1) (752 kg ha^{-1}, 3450 kg ha^{-1}, 42.06 g, 90.23 and 11.96 g, respectively).This higher grain yield under horsegram green manuring has led to significantly higherrainwater use efficiency (0.88 kg ha-mm^{-1}) as compared to sunhemp green manuring (0.77 kg ha-mm^{-1}) and control (0.63 kg ha-mm^{-1}). More kilograms of grain are produced every milliliter of water used, as indicated by the better rainwater usage efficiency under horsegram. The yield and yield characteristics of pigeonpea have not been substantially

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impacted by the interaction effect between the different conservation tillage and in-situ green manuring techniques. However highest and lowest yield, yield parameters were recorded in M_1C_3 and M_3C_1 respectively. The higher grain yield and yield parameters in horsegram*in-situ* green manuring (C_3) was attributed to highest growth, number of branches, leaves, chlorophyll content due to improved physical environment of soil *viz.*, lower bulk density, higher soil moisture available in dry spell period, maximum available nutrients and highest infiltration rate of soil. These results are in conformity with the findings of Jin *et al.* (2009); Bhushan *et al.* (2009); Ghosh *et al*. (2010), Itnal and Palled (2001).

Table 4: Yield and yield parameter of Pigeonpea as influenced by conservation tillage system and *in-situ* green manuring in pigeonpea cropping system

Treatments	**Grain yield (kg ha^{-1})**	**Stalk yield (kg ha^{-1})**	**Yield per plant (g)**	**No. of pods per plant**	**Test weight (g)**	**RWUE (kg ha-mm^{-1})**
Tillage practices						
M_1: Conventional tillage	974	3788	52.07	105.42	13.10	0.82
M_2: Reduced tillage	941	3561	50.16	104.27	13.08	0.79
M_3: Zero tillage	813	3425	46.28	94.31	12.38	0.68
S. Em. ±	**31.2**	**39.80**	**1.12**	**2.31**	**0.15**	**-**
CD (p=0.05)	**122.6**	**156.20**	**4.38**	**9.07**	**0.58**	**-**
***In-situ* green manuring crops**						
C_1: Control	752	3450	42.06	90.23	11.96	0.63
C_2: Sun hemp	921	3554	50.34	101.25	12.98	0.77
C_3: Horsegram	1054	3770	56.11	112.54	13.62	0.88
S. Em. ±	**24.8**	**34.93**	**0.98**	**2.38**	**0.20**	-
CD (p=0.05)	**76.3**	**107.64**	**3.00**	**7.32**	**0.61**	-
Interaction						
M_1C_1	788	3570	43.01	91.83	12.20	0.66
M_1C_2	942	3832	50.86	101.96	13.19	0.79
M_1C_3	1191	3963	62.35	122.48	13.92	1.00
M_2C_1	815	3528	44.05	95.27	12.26	0.68
M_2C_2	984	3473	51.98	105.17	13.30	0.83
M_2C_3	1023	3681	54.45	112.39	13.68	0.86
M_3C_1	654	3251	39.12	83.58	11.42	0.55
M_3C_2	836	3356	48.19	96.62	12.44	0.70
M_3C_3	949	3667	51.54	102.75	13.28	0.80
S. Em. ±	**42.9**	**60.51**	**1.69**	**4.11**	**0.34**	-
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	-

3.5 Economics of pigeonpea production

Agribusiness practice's ultimate goal is to maximize profits for each rupee invested. This provides a clear understanding of the ideal input amount that might be suggested in order to maximize profit as well. Table 5 displays information on cultivation costs, gross returns, net returns, and the benefit to cost ratio (B:C). The results of the study clearly indicated that among different conservation tillage practices reduced tillage (M_2) has recorded lowest cost of cultivation, gross return and highest net return, benefit to cost ratio

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(₹ 27533 ha^{-1}, ₹ 53179ha^{-1}, and ₹ 25646 ha^{-1}, 1.93, respectively) as compared to the highest cost of cultivation, gross return and lowest net return, benefit to cost ratio in conventional tillage (M_1) (₹ 30363ha^{-1}, ₹ 55085 ha^{-1} and ₹ 24722 ha^{-1}, 1.8, respectively).Whereas, practicing zero tillage (M_3) witnessed the lowest cost of cultivation, gross return, net return and B: C ratio (₹ 26073 ha^{-1}, ₹ 46085ha^{-1}, ₹ 20012ha^{-1}, 1.77, respectively) as compared to M_1 and M_2. Since the lower cost of cultivation because of minimum tillage operations involved and higher net returns has increased benefit to cost ratio in the reduced tillage. Similar results were also reported by Kumar and Angadi (2014).

Among different *in-situ* green manuring crop horsegram (C_3) has recorded the highest cost of cultivation, gross returns, net returns, B:C ratio (Rs 28690ha^{-1}, Rs 59478 ha^{-1}, Rs 30788 ha^{-1}, 2.07, respectively) as compared to control (Rs 27190 ha^{-1}, Rs 42740 ha^{-1}, Rs 115550 ha^{-1}, 1.57, respectively).And also, among the interaction combination M_1C_3 (conventional tillage + horsegram) has recorded thehighest cost of cultivation, gross returns, net returns,B:C ratio(₹ 31063 ha^{-1}, ₹ 67090 ha^{-1}, ₹ 36027 ha^{-1}, 2.16,respectively). The probable reason for the increase in gross return, net return, benefit to cost ratio in horsegram (C_3) *in-situ* green manuring may be due to higher grain yield and stalk yield of pigeonpea (1191, 3963 kg ha^{-1},respectively). These results are in conformity with the findings of Singh *et al.* (2015); Li *et al*. (2013); Yadav *et al.* (2011) and Ranjita*et al*. (2007).

Table 5: Economics of pigeonpea as influenced by conservation tillage system and *in-situ* green manuring in pigeonpea cropping system

Treatments	**Cost of cultivation (₹ ha^{-1})**	**Gross return (₹ ha^{-1})**	**Net return (₹ ha^{-1})**	**B: C**
Tillage practice				
M_1: Conventional tillage	30363	55085	24722	1.81
M_2: Reduced tillage	27533	53179	25646	1.93
M_3: Zero tillage	26073	46085	20012	1.77

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***In-situ* green manuring crops**				
C_1: Control	27190	42740	15550	1.57
C_2: Sunhemp	28090	52077	23987	1.85
C_3: Horsegram	28690	59478	30788	2.07
Interaction				
M_1C_1	29563	44768	15205	1.51
M_1C_2	30463	53343	22880	1.75
M_1C_3	31063	67090	36027	2.16
M_2C_1	26733	46236	19503	1.73
M_2C_2	27633	55509	27876	2.01
M_2C_3	28233	57737	29504	2.05
M_3C_1	25273	37270	11997	1.47
M_3C_2	26173	47322	21149	1.81
M_3C_3	26773	53662	26889	2.00

4. Conclusion

Improved aeration and minimum compactness soil and better root development in conventional tillage led more nutrient uptake and which enhanced vegetative growth, and yield attributes in conventional tillage, ultimately increased the grain yield. The excessive mechanical operation in conventional tillage system causes maximum investment and reducing the number of tillage operations to optimum number has increased the benefit to cost ratio. Completely reducing the tillage operations restrict the crop development through excessive compaction, and weed growth. Horsegraminsitu green manuring with reduced tillage operations is the best conservation agriculture technique inorder to retain the soil health for longer period and to achieve the maximum benefit to the rupee invested.

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