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Evaluation of carbon efficient production system through combine effects of tillage and Bioregulators on Rainfed chickpea (*Cicer arietinum* L.)

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Abstract
The field experimentation was carried out at Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India during *rabi* season 2020-21 under rainfed conditions in loamy soil. ZT+R recorded highest total carbon output, net carbon output, carbon efficiency, carbon sustainable index and carbon efficiency ratio followed by zero tillage treatment and minimum reported under conventional tillage treatment. Among bioregulators foliar applications of salicylic acid (50 ppm) at flower initiation and pod filling recorded maximum in carbon efficiency and carbon sustainable index under all tillage treatments while total carbon output, carbon efficiency ratio and net carbon output reported maximum with KNO_3(2%) applications under ZT+R while it was higher with SA (50 ppm) under ZT and CT.

Keywords: Carbon efficiency, carbon efficiency ratio, carbon sustainable index, net carbon output, total carbon output

Introduction
Chickpea (*Cicer arietinum* L.) is one of the major pulse crop of the India. Despite high nutritive value it also fixes atmospheric nitrogen and exude large amount of carboxylates, mainly malonate, citrate and malate Cawthray (2004) [1]. The crop covered 70% area and 65% production. Therefore, it is also known as king of pulses Roy (2021) [12]. Modernization of agriculture changed the land use system and led to increase soil carbon loss (Mann, 1986; Davidson and Ackerman, 1993; Guoand Gifford, 2002) [9, 2, 4] and subsequently reduction in soil health. To counter or mitigate these effect we can change the tillage practices which significantly influenced the soil carbon input (Lampurlanes and Cantero-Martinez, 2003; Martínez *et al.*, 2008) [8, 10] like conservation agriculture can play a key role under rainfed condition to improve water use efficiency, reduce evaporation loss, reduce soil erosion, improve nutrient fixation in soil, improve number of soil microorganism and most importantly it provide carbon efficient production system with higher and long term profitability with lower use of input and give higher output or production. Apart from tillage there are one more approach which can be combined to enhance the output production that is use of various bioregulators which manipulate the plants physiology and morphology to enhance the dry matter production, boost source to sink relation and protect the crop from abiotic stress under rainfed conditions (Pandey *et al.*, 2013) [1]. Thus, the present investigation was carried out to assess the various carbon indices such as net carbon output, carbon efficiency, carbon sustainable index and carbon efficiency ratio. There is a very nearest relationship between agriculture, carbon and soil health. Very meager information is available on this side. Therefore, the present study was attempted to "Evaluation of carbon efficient production system through combine effects of tillage and bioregulators on rainfed chickpea (*Cicer arietinum* L.)"

Materials and Methods
The field study was conducted at Rani Lakshmi Bai Central Agricultural University, Jhansi,

Uttar Pradesh, India during *rabi* season 2020-21 under rainfed condition in loam soil. The experimental site is located at 25°31'07.1" N latitude and longitude of 78°33'47.4 E with 284 meters above from mean sea level (MSL). The experimental soil texture was approximately neutral in pH-7.2 and EC was 0.189 ds/m.

The fertility status of soil was medium in OC (0.51%), low in available N (197.0 kg/ha), medium in available P (18.20 kg/ha) and S (14.40 kg/ha) and high in K (357.10 kg/ha). The experimentation was outlined in split plot design where 3 levels of tillage namely conventional tillage, zero tillage, and zero tillage with black gram crop residue (5 t/ha) was assigned to the main plot and five different bioregulators namely control (water spray), salicylic acid (50 ppm), Potassium nitrate (2%), Thiourea (1000 ppm), and Potassium + Multi-micronutrient complex (1%) assigned to sub plots with applied as foliar spray at flower initiation and pod filling stage. The seed rate of chickpea crop variety RVG-202 (Desi chickpea) was 60 kg/ha with recommended dose of fertilizers, 20 kg nitrogen, 50 kg phosphorus/ha and 20 kg K_2O/ha was applied. The crop received 2.0, 1.0, 3.8, 4.6 and 4.2 mm of precipitation on 47th, 6th, 7th, 11th and 12th meteorological weeks respectively. However 15.6 mm of total rainfall received by chickpea thought the growing season.

Carbon auditing

Crop output is comes in terms of economic or biological yield. Carbon output was computed by multiplying with an average carbon content of biomass (44% on a dry weight basis) moreover C-equivalent (CE) was computed by multiplying the quantity of various inputs used in the process of crop production by the respective emission coefficients (Table 1) as described by Lal (2016) [7]. The C-budgeting *viz*, Carbon output, Carbon efficiency (CE), Carbon sustainability index (CSI), Carbon efficiency ratio (CER) under various tillage and bioregulators level systems was computed by using the following equations:

Carbon output (kg CE per ha^{-1}) = Total biomass (economic yields + by product of yields) x 0.44

$$(1)\ \text{Carbon efficiency(CE)} = \frac{\text{Carbon output}}{\text{Carbon input}}$$

$$(2)\ \text{Carbon sustainibility index (CSI)} = \frac{\text{Carbon output} - \text{Carbon intput}}{\text{Carbon Input}}$$

$$(3)\ \text{Carbon efficiency ratio (CER)} = \frac{\text{Grain yield in termms of carbon}}{\text{Carbon Input}}$$

Table 1: Carbon equivalent for different input, output and machinery

Operation	Unit	Kg CO_2e unit^{-1}	References
Fertilizers			
Nitrogen	kg	4.96	Lal (2004) [6]
Phosphorus	kg	1.35	Lal (2004) [6]
Potash	kg	0.58	Lal (2004) [6]
Chickpea Seed	kg	1.22	Wang (2015) [13]
Bioregulators			
KNO_3	kg	0.43	On the basis of nutrient composition
Thiourea	kg	4.96	On the basis of nutrient composition
K+ multimicronuutrients	kg	0.58	On the basis of nutrient composition
Plant protection			
Fungicides	Litre	3.90	Lal (2004) [6]
Glyphosate(Herbicides)	litre	6.30	Lal (2004) [6]
Human Labour	Man-days	0.86	Wang (2015) [13]
Electricity	kWh	0.075	Lal (2004) [6]
Diesel	litre	3.32	Deng (1985) [3]
Diesel farm machinery	hours	3.32	Deng (1985) [3]

Results and Discussion

Carbon input consumption

The data presented in table 2 represent common carbon input consumed (296.81 Kg CO_2e per ha) in chickpea production. Seed is very basic and essential part of sowing input for crop cultivation and it was contributed 24.66% of total common carbon input consumption while diesel required for sowing of seeds contributed to 8.94% of total common carbon input consumption, moreover there was some labour work force also used in terms of man days for various operations like gap filling, Harvesting and Threshing manual, plant protection application etc., however the contribution of man days was 4.34% of total common carbon input. Fertilizer application was accounted for the highest 60.07% of total common carbon input which was valued 178.30 Kg CO_2e per ha. However nitrogen application rate is less (20 kg/ha) but it contributed to highest share (55.63%) among other fertilizers. common carbon input share of plant protection chemicals shared only 1.97% of total common carbon input. Carbon input consumption was used in tillage treatments represented in table 3. Among different tillage treatments CT contributed highest carbon input (176.11 Kg CO_2e per ha). It may be due to additional inputs was used in CT treatments like harrow, planker and one additional pre-emergence herbicide application as compared to ZT (61.79 Kg CO_2e per ha) and ZT+R (61.79 Kg CO_2e per ha) where direct sowing was done by happy seed drill machine. Among bioregulators foliar application of KNO_3 (218.7 Kg CO_2e per ha) was shared maximum to carbon input consumption followed by K+ multimicronutrient (12.46 Kg CO_2e per ha), thiourea (5.82 Kg CO_2e per ha), salicylic acid (0.86 Kg CO_2e per ha) and control or water spray (0.86 Kg CO_2e per ha). It may be due to higher nutrient content in bioregulators as compared to water spray.

Table 2: Energy input requirement for different tillage treatments

Tillage	Used quantity	Kg CO_2e unit^{-1}	Total Kg CO_2e per ha
Conventional tillage			
Pendimethalin	1 kg	6.30	6.30
Tractor+ Cultivator	3 hrs	3.32	9.96
Tractor+ Harrow	1.5 hrs	3.32	4.98
Tractor+ Planker	1.5 hrs	3.32	4.98
Tractor+ Happy Seed drill	2.5 hrs	3.32	8.3
Diesel	39.8 l	3.32	132.13
Driver +Labour	11 man hours	0.86	9.46
			176.11
Zero tillage			
Glyphosate	1.23 kg	6.30	7.75
Knapsack sprayer	4 hrs	-	
Application	4 man hours	3.32	13.28
Happy Seed Drill+ Tractor	1.5 hrs	3.32	4.98
Diesel	10 l	3.32	33.2
Driver+ Human labour	3 man hrs	0.86	2.58
			61.79
Zero tillage+ Residue			
Glyphosate	1.23 kg	6.30	7.75
Knapsack sprayer	4 hrs	-	
Application	0.5 man hours	3.32	13.28
Happy Seed Drill+ Tractor	1.5 hrs	3.32	4.98
Diesel	10 l	3.32	33.2
Driver+ Human labour	3 man hrs	0.86	2.58
			61.79

Table 3: Energy input requirement for different tillage treatments

Bioregulators	Used quantity	Kg CO_2e unit^{-1}	Total Kg CO_2e per ha
Salicylic acid	50 g	-	-
Water	1 m^3		
Knapsack sprayer	8 hrs		
Application	1 man days	0.86	0.86
			0.86
KNO_3	20 Kg	0.43	13.43
Water	1 m^3		
Knapsack sprayer	8 hrs		
Application	1 man days	0.86	0.86
			14.29
Thiourea	1 Kg	4.96	4.96
Water	1 m^3		
Knapsack sprayer	8 hrs		
Application	1 man days	0.86	0.86
			5.82
K+multimicronutrient	10+10 kg	0.58	11.6
Water	1 m^3		
Knapsack sprayer	8 hrs		
Application	1 man days	0.86	0.86
			12.46
Water			
Water	1m^3		
Knapsack sprayer	8 hrs		
Application	1 man days	0.86	0.86
			0.86

Carbon input-output relationship

Total carbon output of biomass was computed by multiplying it with an average carbon content of biomass (44% on a dry weight basis) moreover C-equivalent (CE) was computed by multiplying the quantity of various inputs used in the process of crop production by the respective emission coefficients as described by Lal (2016) [7]. Total carbon output of biomass was highly affected by total grain and stover production. Maximum carbon output recorded in ZT+R (1790.58 kg CE per ha) followed by ZT and CT. it was due to higher biomass yield recorded in ZR+R treatment because it provided more favorable environment as compared to ZT and CT under rainfed condition. Among bioregulators foliar application of KNO_3 (1790.58 Kg CO_2e per ha) recorded maximum carbon output while control or water spray (1460.01 Kg CO_2e per ha) recorded minimum carbon. It may be due to incensement of total biomass production with bioregulators leads to increased total carbon output. Foliar application of SA shared highest carbon output in ZT and CT treatment as compared to other treatments which was a result of higher grain and straw yield.

Net carbon returns

The net carbon returns is presented in table 5. ZT+R achieved maximum net carbon returned over CT and ZT. It was due to higher input carbon incurred as well as lower carbon output in CT treatment resulted in lower net carbon returns as compared to ZT and ZT+R. In bioregulators foliar application of SA shared maximum net carbon returned as compared to other treatments while lowest net carbon was returned from control or water spray under ZT and CT tillage treatments while foliar spray of KNO_3 reported highest net carbon output over other treatments under ZT+R.

Carbon efficiency (CE)

Carbon efficiency or carbon output to carbon input ratios of different treatments are presented in table5. Carbon efficiency was higher under ZT+R treatment (4.49) over ZT (4.19) and CT(3.08), however ZT was also recorded higher carbon efficiency as compared to CT. it may be due to higher carbon output with lower carbon input under ZT+R followed by ZT and CT. Foliar application of SA (50ppm) showed higher carbon output per unit of carbon input, as compared to other treatments under all tillage practices. It is due to highest grain and stover yields was reported which was leads to more carbon efficiency in SA application over other treatment. Foliar application of SA (50 ppm) under ZT+R was recorded 46% more carbon efficiency over same application under CT.

Carbon sustainability index (CSI)

Net carbon output to carbon input is presented in table 5. CSI represent the amount of net carbon production with each unit of carbon input. CSI was higher under ZT+R (3.49) over ZT (3.19) and CT (2.08), however ZT was also recorded higher carbon sustainability index over CT. It might be due to higher net carbon output with lower carbon input under ZT+R followed by ZT and CT. CSI was more under ZT+R as comparatively compared to ZT and CT. Foliar spray of SA (50ppm) showed higher carbon sustainability index, as compared to other bioregulator treatments under all tillage practices. It is due to highest biomass yields were reported leads to more net carbon content and subsequently higher CSI reported. Foliar application of SA (50 ppm) under ZT+R was recorded 66% more carbon efficiency over same application under CT.

Carbon efficiency ratio (CER)

The ratio of grain yields in terms of carbon to carbon input presented in table5. CER reported higher under ZT+R (1.24) as compared to ZT (1.09) and CT (0.75), however ZT reported more CER as compared to CT. It might be due to higher grain yield with lower input carbon leads to more carbon output and subsequently higher carbon efficiency ratio under ZT+R as compared to ZT and CT. Among bioregulator, foliar spray of salicylic acid (1.46) and KNO_3 (1.47) followed by K + multi-micronutrient (1.38), thiourea (1.29) and minimum with control (1.24) under ZT+R. while in case of ZT and CT, maximum CER were reported with foliar spray of Salicylic acid and minimum with control. Foliar application of SA (50 ppm) under ZT+R was recorded approximately 42% more carbon efficiency over same application under CT.

Table 4: Carbon output and carbon input influenced by tillage and bioregulators applications in chickpea as

Treatment	Common input	Tillage	Bioregulators	Total carbon input (Kg CE) Per ha)	Total carbon output (kg CE per ha)
CT-Conventional tillage					
B_0 - Control (water spray)	296.81	176.11	0.86	473.78	1460.01
B_1- Salicylic acid (50 ppm)	296.81	176.11	0.86	473.78	1572.80
B_2- KNO_3 (2%)	296.81	176.11	14.29	487.21	1530.94
B_3- Thiourea (1000 ppm)	296.81	176.11	5.82	478.74	1524.74
B_4 - K + multi-micronutrient (1%)	296.81	176.11	12.46	485.38	1442.91
ZT-Zero tillage					
B_0 - Control (water spray)	296.81	61.79	0.86	359.46	1507.68
B_1- Salicylic acid (50 ppm)	296.81	61.79	0.86	359.46	1707.75
B_2- KNO_3 (2%)	296.81	61.79	14.29	372.89	1610.76
B_3- Thiourea (1000 ppm)	296.81	61.79	5.82	364.42	1599.41
B_4 - K + multi-micronutrient (1%)	296.81	61.79	12.46	371.06	1569.75
ZT+R Zero tillage + residue					
B_0 - Control (water spray)	296.81	61.79	0.86	359.46	1615.54
B_1- Salicylic acid (50 ppm)	296.81	61.79	0.86	359.46	1748.39
B_2- KNO_3 (2%)	296.81	61.79	14.29	372.89	1790.58
B_3- Thiourea (1000 ppm)	296.81	61.79	5.82	364.42	1697.41
B_4 - K + multi-micronutrient (1%)	296.81	61.79	12.46	371.06	1738.89

Table 5: Net carbon output, carbon efficiency, CSI and CSR) in chickpea as influenced by tillage and bioregulators applications

Treatment	Net carbon output (kg CE per ha)	Carbon efficiency (CE)	Carbon sustainability index (CSI)	Carbon efficiency ratio (CER)
CT-Conventional tillage				
B_0 - Control (water spray)	986.23	3.08	2.08	0.75
B_1- Salicylic acid (50 ppm)	1099.02	3.32	2.32	0.85
B_2- KNO_3 (2%)	1043.73	3.14	2.14	0.80
B_3- Thiourea (1000 ppm)	1046	3.18	2.18	0.84
B_4 - K + multi-micronutrient (1%)	957.53	2.97	1.97	0.78
ZT-Zero tillage				
B_0 - Control (water spray)	1148.22	4.19	3.19	1.09
B_1- Salicylic acid (50 ppm)	1348.29	4.75	3.75	1.33
B_2- KNO_3 (2%)	1237.87	4.32	3.32	1.16
B_3- Thiourea (1000 ppm)	1234.99	4.39	3.39	1.15
B_4 - K + multi-micronutrient (1%)	1198.69	4.23	3.23	1.07
ZT+R Zero tillage+Residue				
B_0 - Control (water spray)	1256.08	4.49	3.49	1.24
B_1- Salicylic acid (50 ppm)	1388.93	4.86	3.86	1.46
B_2- KNO_3 (2%)	1417.69	4.80	3.80	1.47
B_3- Thiourea (1000 ppm)	1332.99	4.66	3.66	1.29
B_4 - K + multi-micronutrient (1%)	1367.83	4.69	3.69	1.38

Conclusion

Chickpea are mostly cultivated in rainfed conditions under marginal soil conditions so it is important to study the efficient carbon input management for achieving sustainable output under clean environment. ZT+R recorded highest total carbon output, net carbon output, carbon efficiency, carbon sustainable index and carbon efficiency ratio followed by zero tillage treatment and minimum reported under conventional tillage treatment. Among bioregulators foliar applications of salicylic acid (50 ppm) at flower initiation and pod filling recorded maximum in carbon efficiency and carbon sustainable index under all tillage treatments while total carbon output, carbon efficiency ratio and net carbon output reported maximum with KNO_3 (2%) applications under ZT+R while it was higher with SA (50 ppm) under ZT and CT.

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References

1. Cawthray G, Scanlon T. Carboxylate concentrations in the rhizosphere of lateral roots of chickpea (*Cicer arietinum*) increase during plant development, but are not correlated with phosphorus status of soil or plants. New Phytologist. 2004;162:745-753.
2. Davidson EA, Ackerman IL. Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochemistry. 1993;20:161-193.
3. Deng JL. Grey control system. Hua Zhong Institute of Technology Press. China, 1985.
4. Guo LB, Gifford RM. Soil carbon stocks and land use change: Ameta-analysis. Glob. Change Biol. 2002;8:345-360.
5. Kumar R, Mishra JS, Mondal S, Meena RS, Sundaram PK, Bhatt BP, *et al*. Designing an ecofriendly and carbon-cum-energy efficient production system for the diverse agro ecosystem of South Asia. Energy. 2021;214:118860.
6. Lal R. Carbon emission from farm operations. Environment international. 2004;30(7):981-990.
7. Lal S, Dubey RP, Das GK, Suryavanshi T. Energy budgeting of weed management in soybean, 2016.
8. Lampurlanes J, Cantero-Martinez C. Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with barley root growth. Agron. J. 2003;95:526-536.
9. Mann LK. Changes in soil carbon storage after cultivation. Soil Science. 1986;142(5):279-288.
10. Martínez E, Fuentes JP, Silva P, Valle S, Acevedo E. Soil physical properties and wheat root growth as affected by no-tillage and conventional tillage systems in a Mediterranean environment of Chile. Soil Till. Res. 2008;99:232-244.
11. Pandey M, Srivastava AK, D'Souza SF, Penna S. Thiourea, a ROS scavenger, regulates source-to-sink relationship to enhance crop yield and oil content in *Brassica juncea* (L.). PloS one. 2013;8(9):e73921.
12. Roy Deepayan, Chauhan Arvind, Singh Prabhat. Chickpea: The King of Pulse Crops, 2021. 10.22271/ed.book.1390.
13. Wang H, Yang Y, Zhang X, Tian G. Carbon footprint analysis for mechanization of maize production based on life cycle assessment: A case study in Jilin Province, China. Sustainability. 2015;7(11):15772-15784.