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Correlation and regression studies on weed density with weed dry weight and Weed density with chickpea seed yield under Jatropha based Agroforestry

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Abstract
The study was initiated to evaluate the growth attributes of the chickpea (gram) crop under the *Jatropha curcas* based Agroforestry system all over the years 2019–20 and 2020–21 in an 8–9 year old *Jatropha curcas* plantation, planted at a distance of 3x3m. Correlation coefficient of *Cyprus rotundus* (0.934) and *Medicago denticulata* (0.971) had highest positive correlation with the weed dry weight during 2019-20 and 2020-21, respectively. The *Cynodon dactylon* had lowest correlation coefficient with the weed dry weight (0.886) during first year (2019-20) and *Cyprus rotundus* (0.914) was found during (2020-21). Regression coefficient of *Medicago denticulata* contributed to the greater extent for weed dry weight production with increase of one plant, the increase in weed dry weight could be predicted by 1.344 q ha^{-1} followed by *Cyprus rotundus* 0.936 q ha^{-1}, *Cynodon dactylon* 0.439 q ha^{-1} and *Vicia sativa* 0.111 q ha^{-1} during first year (2019-20) and *Cyprus rotundus* 0.525 q ha^{-1} followed by *Vicia sativa* 0.378 q ha^{-1}, *Cynodon dactylon* 0.370 q ha^{-1} and *Medicago denticulata* 0.271 q ha^{-1} during second year (2020-21). Correlation coefficient *Cyprus rotundus* had highest negative association with Chickpea seed yield (-0.816 and -0.938 q ha^{-1}) during both the years. Regression coefficient data revealed that the reduction in yield could be predicted to extent of 2.026 q ha^{-1} with increase of one plant of *Cyprus rotundus.* The greater reduction in yield can also be predicted due to density of *Cynodon dactylon, Medicago denticulate,* and *Vicia sativa.* The reduction could be predicted by 0.975, 0.619 and 0.579 q ha^{-1} respectively during first year (2019-20). However, during second year (2020-21) *Cyprus rotundus* reduced highest extent of chickpea seed yield (2.803 q ha^{-1}) with increase of one plant followed by *Vicia sativa, Cynodon dactylon,* and *Medicago denticulata.* The reduction could be predicted by 1.59, 1.57 and 1.046 q ha^{-1} with increase of one plant of weed species, respectively. The greater reduction in chickpea seed yield can also be predicted due to density of *Cynodon dactylon, Vicia sativa* and *Medicago denticulate* weed species under gram – Jatropha based Agroforestry system.

Keywords: *Jatropha curcas,* correlation, regression, growth characters, chickpea (gram), and yield

Introduction
In diverse agro-ecological settings, Agroforestry is a great way to boost land productivity, expand the outside forest cover, and lessen human strain on the woods. It is also a practical means of averting and minimizing change. One option for the sustainable management of natural resources is Agroforestry. Farmers have used this land-use method for generations to combine trees or perennials, crops, and animals. Increase, diversification, and sustainability of production of economic, environmental, and social benefits are the aims of Agroforestry systems. The most significant and effective agricultural strategy to reduce land degradation is Agroforestry. It promotes soil fertility, lessens weed infestation and erosion, enhances water quality, boosts biodiversity, improves aesthetics, and captures carbon. For the farmer, Agroforestry constantly remains productive and provides ongoing revenue. The Agroforestry system, which incorporates perennial woody plants, is the most appropriate technique to boost the total output of food, feed, and fuel, therefore lowering the danger of weed infestation in agriculture, given the declining amount of per capita land. Many forward-thinking farmers have created or changed existing Agroforestry systems to fit their region's needs.

Tree Born Oil Seeds (TBO) is compatible with the majority of these systems and enhances overall production and farm profitability. Jatropha (Jatropha curcas) plantations on fallow land were the main focus of the initial programs, but limited and highly variable seed yields under low input conditions resulted in economic unavailability and restricted production potential (Achten *et al.*, 2014; Van Eijck *et al.*, 2014) [1, 13]. One of the oldest and most frequently farmed legumes in India is the chickpea (*Cicer arietinum* L.). It is mostly grown in Madhya Pradesh, Maharashtra, Andhra Pradesh, Rajasthan, and Odisha in our nation. India produces the most chickpeas in the world, making over 75% of the total. Due to their modest size and poor early development, chickpeas are particularly vulnerable to weed competition. If the weeds are not promptly eradicated, considerable losses can frequently result. As the crop is planted in the post-rainy season under rainfed and dry land conditions, weed competition with chickpea becomes more significant, necessitating prompt and thorough weed management. For nutrients, moisture, light, and space, weeds fiercely fight with crops, resulting in production losses of up to 75% in chickpeas (Chaudhary *et al.*, 2005) [4]. Herbicides are plant protection agents that are used to undesirable weeds in high-input agriculture to eliminate production losses brought on by these noxious plants (Cork and Krueger, 1992) [15]. Weeds must be controlled quickly and effectively using the right techniques to get a greater yield. Herbicides are frequently used because weed management is simple and labor-intensive, especially during the crucial time. Chickpea fields are overrun with more than 75 different types of weeds. The majority of these species are dicotyledonous, and they are members of 26 distinct families (El-Brahli, 1988) [6]. About 24% of the world's grain production comes from it. Given the huge consumption of this staple crop, any improvement in growth characteristics may have a substantial effect on global human consumption. The current investigation was conducted while taking into consideration the aforementioned facts. Crops have been the subject of several correlation and route analysis studies. Noor *et al.* (2003) [9], Arshad *et al.* (2004) [2], Atta *et al.* (2008) [3] showed correlation coefficients between yield and yield components as well as direct and indirect impacts of several plant characteristics on yield and yield components.

Materials and Methods

In 8-9 years old JATROPHA plantation planted at a distance of 3 m x 3 m, the study was started to determine the association between growth characteristics of Gram plants under a Jatropha curcas based Agroforestry system in 2019–20. The test field's soil was almost completely neutral and had a clayey texture. The soil contained 288 (medium), 20 (medium), and 170 (extremely low) kg/ha, respectively, of nitrogen, phosphorus, and potash. Jabalpur is 411.78 m above mean sea level and is situated at 23.3°N latitude and 79.5°E longitude. It is referred to as the Madhya Pradesh rice-wheat growing region and is part of the Kymore Plateau and Satpura Hills agro-climatic zones. The subtropical climate of the area is characterized by hot, dry summers and chilly, dry winters. 1250 to 1400 mm of rain precipitation occurs on average each year in Jabalpur. Most of the time, rain falls between mid-June and September, with sporadic downpours in winter. In the summer, the monthly average temperature can reach 45 °C. The overall correlation between the various variables was observed due to the long lifespan of trees, a function of the direct and indirect relationship between various variables, in order to measure the direct influence of one variable on another and to allow the division of the correlation coefficient into a component of the direct effect of a predictor variable on its response variable and indirect effects of a predictor variable in the integrated structure of the plant. A crucial component of studies on variation and selection is the analysis of growth features. The intricate link between many development features in a biological system is explained by the correlation and regression studies. Multivariate approaches are increasingly being employed in the analysis of biological data as a result of advancements in computer programming. The various growth features must be linearly correlated, and the effects of the growth traits on yield must be measured.

According to Sendecor and Cochran's (1967) [10] recommendations, the correlation matrix between different crop and tree development traits, wheat production, and tree stand biomass was determined using the following method.

$$\text{Correlation coefficient}(r) = \frac{\sum xy - \frac{(\sum x)\ x\ (\sum y)}{N}}{\sqrt{\frac{\sum y^2 - (\sum y)^2}{n} \cdot \frac{\sum x^2 - (\sum x)^2}{n}}}$$

Where,
R: Correlation
$\sum X$: ADD up all the X scores
$\sum Y$: add up all the Y scores
$\sum X^2$: Square each X scores and then add them up
$\sum Y^2$: Square each Y scores and then add them up
$\sum XY$: Multiply each X score by its associated Y score and Then add the resulting products
N: Number of Pairs of data

Regression models were applied, and the coefficient was linked to understand the quantitative change in yield, in order to forecast the impacts of weeds on gram crop production. The regression equation shown below was employed.

$\hat{Y} = a + bx$

Where, $\hat{Y}$ = yield
X = variables
A and b are regression constant and regression coefficient, respectively.

Result and Discussion

Correlation coefficient between weed density with weed dry weight

The data and results presented in Table 1 showed that the correlation coefficients analysis revealed that *Cyprus rotundus* (0.934) and *Medicago denticulata* (0.971) had highest positive correlation with the weed dry weight during 2019-20 and 2020-21, respectively. However, *Medicago denticulata* (0.914 and 0.971) and *Vicia sativa* (0.899 and 0.914) had highest and at par positive correlation during both the year. The *Cynodon dactylon* had lowest correlation coefficient with the weed dry weight (0.886) during first year (2019-20) and *Cyprus rotundus* (0.914) was found during (2020-21). The pooled analysis of two years (2019-20 and 2020-21) revealed that *Medicago denticulata* (0.954) had highest positive correlation with weed dry weight and at par with *Vicia sativa* (0.928). Whereas, *Cyprus rotundus* (0.906) found lower correlation coefficient under gram - Jatropha based Agroforestry system. The similar finding was also reported by Jain and Sharma (2011) [7], Singh *et al.* (2014) [11], Tadesse *et al.* (2016) [12] and Kumar *et al.* (2019) [8].

Table 1: Correlation coefficient between weed density (m^{-2}) with weed dry weight (q ha^{-1})

Character	*Cyprus rotundus*	*Medicago denticulata*	*Vicia sativa*	Total weed	Dry Weight (q ha^{-1})
	X_2	X_3	X_4	X_5	X_6
2019-20					
X_1-*Cynodon dactylon*	0.866**	0.950**	0.940**	0.977**	0.886**
X_2-*Cyprus rotundus*	-	0.853**	0.851**	0.899**	0.934**
X_3-*Medicago denticulata*	-	-	0.941**	0.982**	0.914**
X_4-*Vicia sativa*	-	-	-	0.978**	0.899**
X_5-Total weed	-	-	-	-	0.933**
2020-21					
Character	X_2	X_3	X_4	X_5	X_6
X_1-*Cynodon dactylon*	0.885**	0.940**	0.933**	0.982**	0.914**
X_2-*Cyprus rotundus*	-	0.824**	0.839**	0.905**	0.834**
X_3-*Medicago denticulata*	-	-	0.912**	0.973**	0.971**
X_4-*Vicia sativa*	-	-	-	0.963**	0.914**
X_5-Total weed	-	-	-	-	0.958**
Pooled					
Character	X_2	X_3	X_4	X_5	X_6
X_1-*Cynodon dactylon*	0.877**	0.952**	0.940**	0.981**	0.913**
X_2-*Cyprus rotundus*	-	0.845**	0.842**	0.901**	0.906**
X_3-*Medicago denticulata*	-	-	0.938**	0.981**	0.954**
X_4-*Vicia sativa*	-	-	-	0.974**	0.928**
X_5-Total weed	-	-	-	-	0.961**

Note:
* -sign indicate significant at 0.05 level of significance.
** -sign indicate significant at 0.01 level of significance.

Regression coefficient between weed density with weed dry weight

The regression analysis (Table 2 and Figure 1, 2 and 3) revealed that the *Medicago denticulata* contributed to the greater extent for weed dry weight production with increase of one plant, the increase in weed dry weight could be predicted by 1.344 q ha^{-1} followed by *Cyprus rotundus* 0.936 q ha^{-1}, *Cynodon dactylon* 0.439 q ha^{-1} and *Vicia sativa* 0.111 q ha^{-1} during first year (2019-20) and *Cyprus rotundus* 0.525 q ha^{-1} followed by *Vicia sativa* 0.378 q ha^{-1}, *Cynodon dactylon* 0.370 q ha^{-1} and *Medicago denticulata* 0.271 q ha^{-1} during second year (2020-21). The pooled analysis of two years (2019-20 and 2020-21), revealed that *Cyprus rotundus* contributed to the greater extent for weed dry weight production with increase of one plant, the increase in weed dry weight could be predicted by 0.726 q ha^{-1} followed by *Cynodon dactylon* 0.421 q ha^{-1}, *Vicia sativa* 0.352 q ha^{-1}, *Medicago denticulata* 0.296 q ha^{-1}. The similar finding was also reported by Jain and Sharma (2011) [7], Singh *et al.* (2014) [11], Tadesse *et al.* (2016) [12] and Kumar *et al.* (2019) [8].

Table 2 Regression between weed density (m^{-2}) with weed dry weight (q ha^{-1})

Character	$\hat{Y} = a + bx$	Coefficient of determination (R^2)
2019-20		
X_1-*Cynodon dactylon*	$\hat{Y} = 0.813 + 0.459\ x_1$	0.784
X_2-*Cyprus rotundus*	$\hat{Y} = -1.372 + 0.936\ x_2$	0.872
X_3-*Medicago denticulata*	$\hat{Y} = 0.309 + 1.344\ x_3$	0.835
X_4-*Vicia sativa*	$\hat{Y} = 1.350 + 0.323\ x_4$	0.808
X_5-Total weed	$\hat{Y} = 0.766 + 0.111\ x_5$	0.870
2020-21		
X_1-*Cynodon dactylon*	$\hat{Y} = 1.147 + 0.370\ x_1$	0.835
X_2-*Cyprus rotundus*	$\hat{Y} = 0.631 + 0.525\ x_2$	0.696
X_3-*Medicago denticulata*	$\hat{Y} = 1.478 + 0.271\ x_3$	0.942
X_4-*Vicia sativa*	$\hat{Y} = 0.883 + 0.378\ x_4$	0.835
X_5-Total weed	$\hat{Y} = 0.934 + 0.099\ x_5$	0.917
Pooled		
X_1-*Cynodon dactylon*	$\hat{Y} = 0.951 + 0.421\ x_1$	0.833
X_2-*Cyprus rotundus*	$\hat{Y} = -0.316 + 0.726\ x_2$	0.821
X_3-*Medicago denticulata*	$\hat{Y} = 1.379 + 0.296\ x_3$	0.909
X_4-*Vicia sativa*	$\hat{Y} = 1.105 + 0.352\ x_4$	0.861
X_5-Total weed	$\hat{Y} = 0.809 + 0.107\ x_5$	0.923

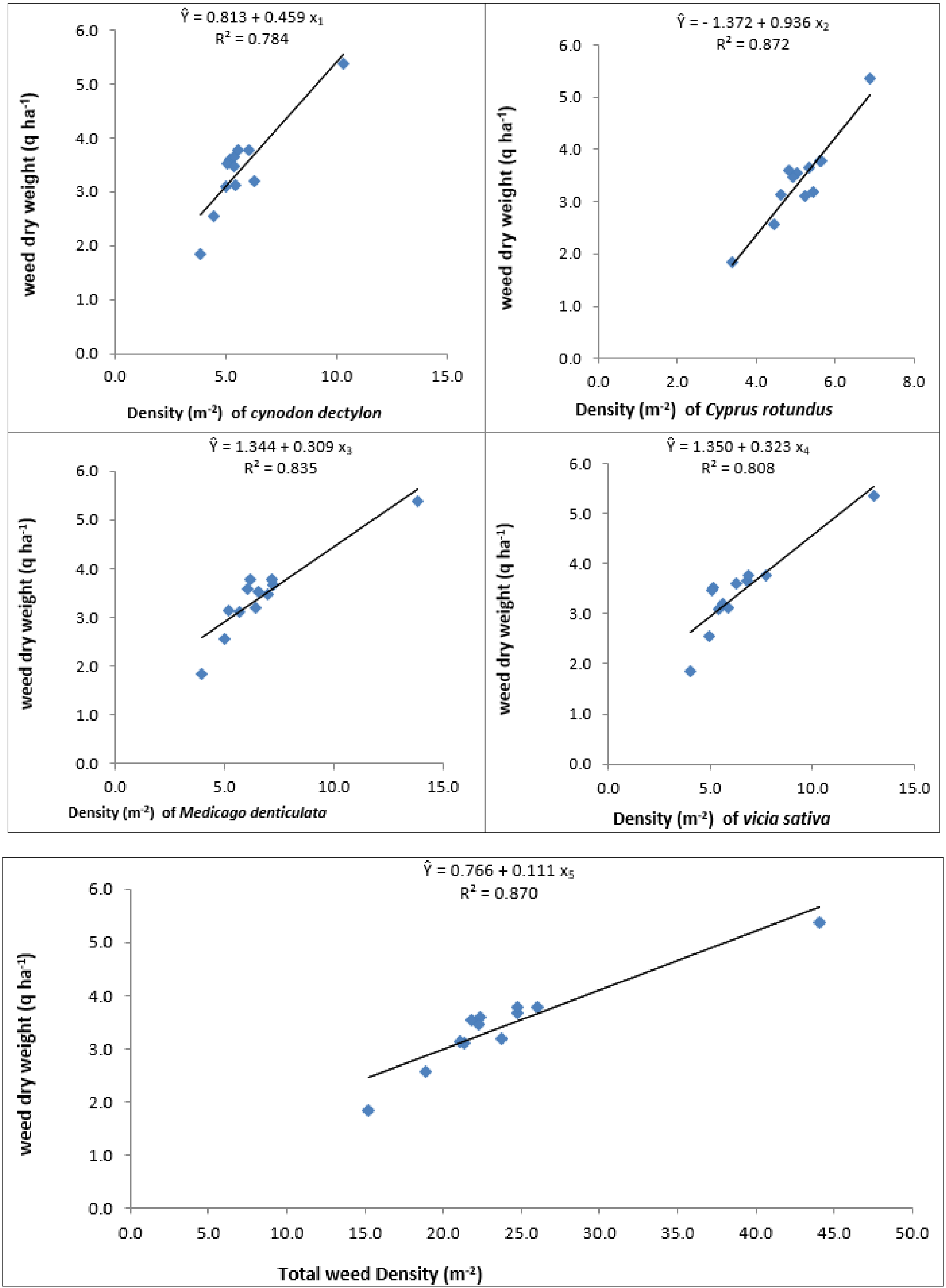


Fig 1: Regression of weed density (m^{-2}) of different species on total weed dry weight production (q ha^{-1}) during first year (2019-20)

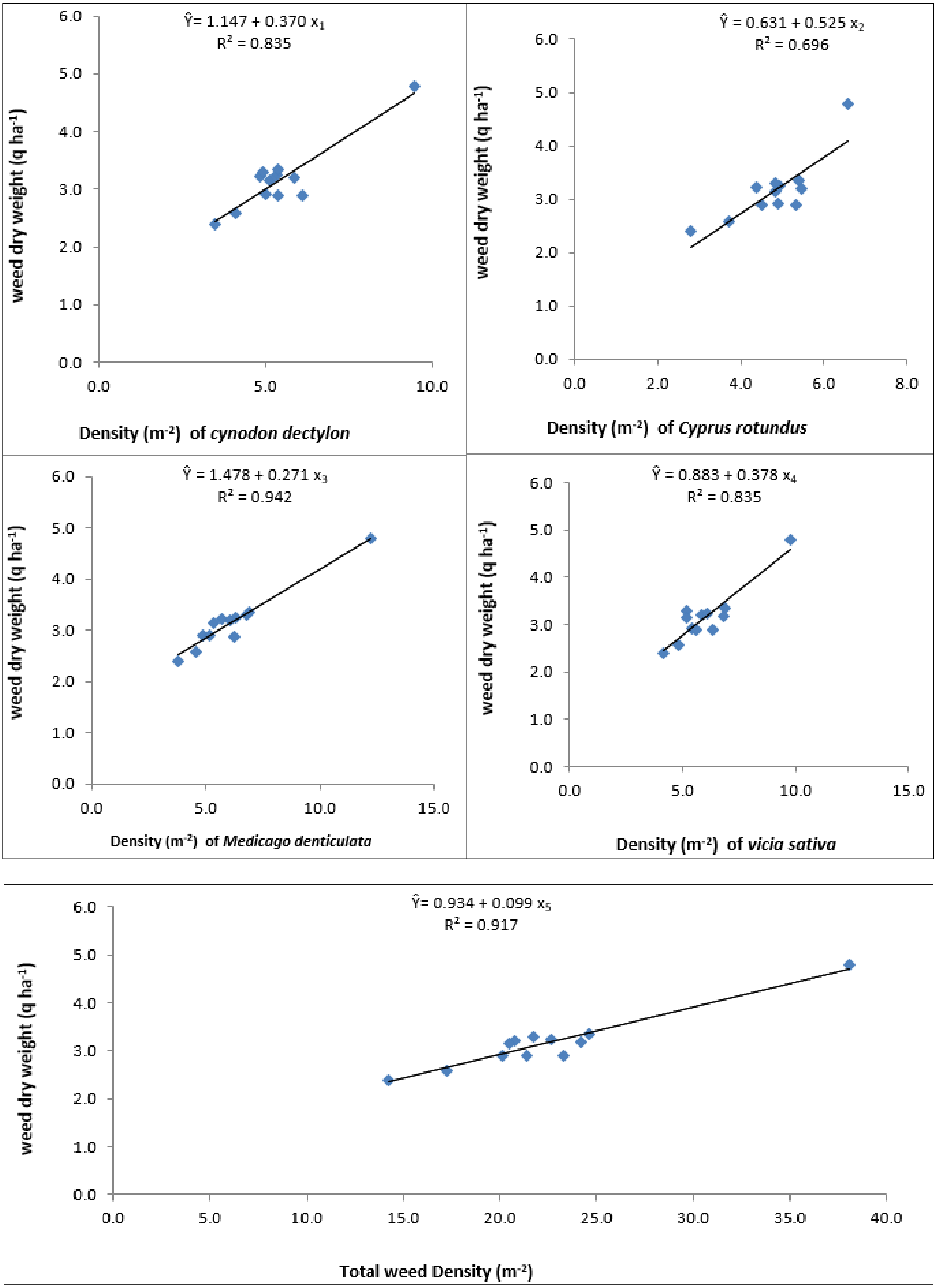


Fig 2: Regression of weed density (m^{-2}) of different species on total weed dry weight production (q ha^{-1}) during second year (2020-21)

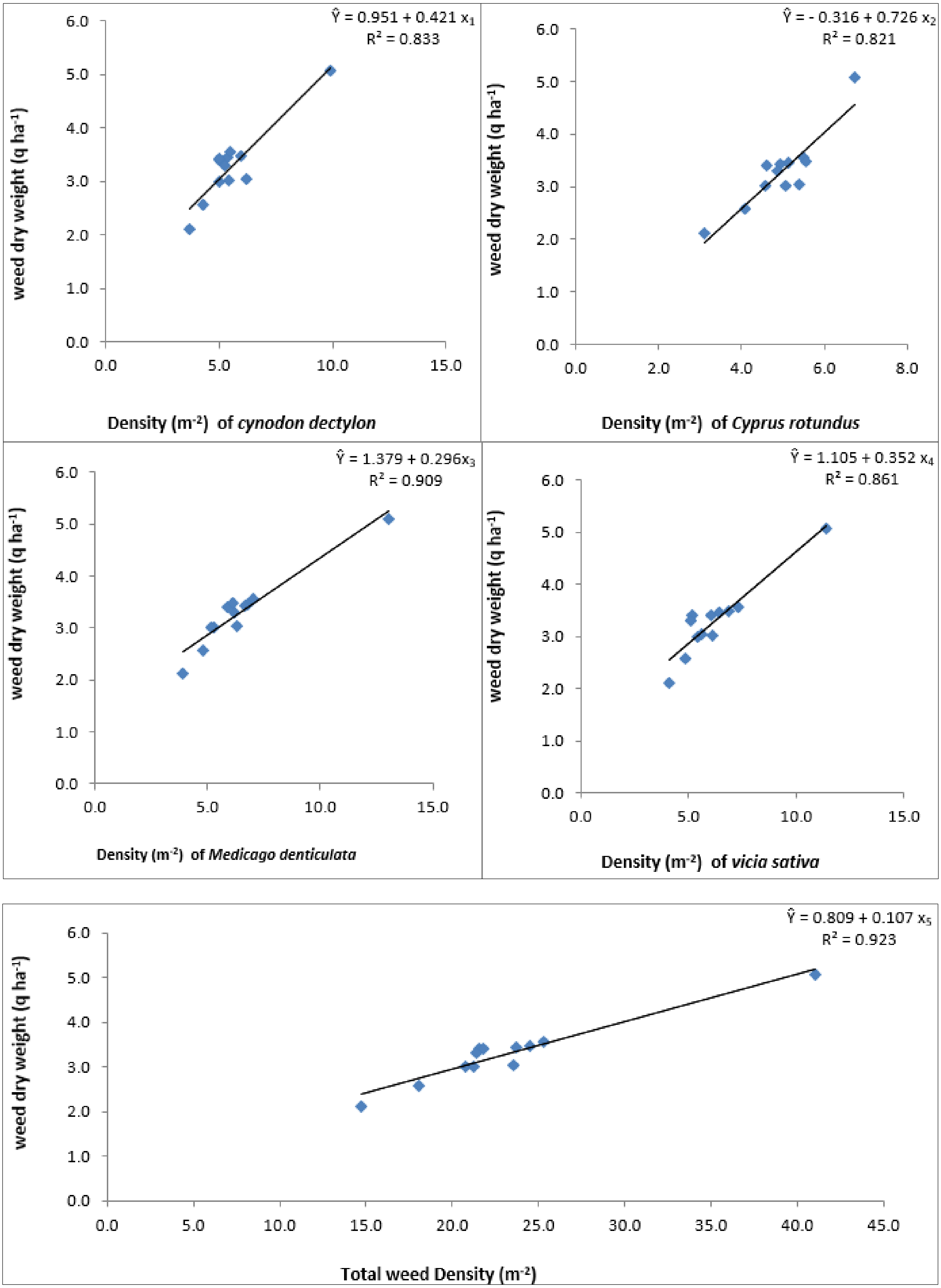


Fig 3: Pooled Regression of weed density (m^{-2}) of different species on total weed dry weight production ($q\ ha^{-1}$)

Correlation coefficient between Weed density with chickpea seed yield

The correlation amongst weed density of different species with chickpea seed yield was found negative (Table 3). The correlation analysis data revealed that *Cyprus rotundus* had highest negative association with chickpea seed yield (-0.816 and -0.938 q ha^{-1}) during both the years. The pooled analysis (2019-20 and 2020-21), revealed that *Cyprus rotundus* (-0.911 q ha^{-1}) had highest negative correlation with seed yield under gram – Jatropha based Agroforestry. The similar finding was also reported by Jain and Sharma (2011) [7], Singh *et al.* (2014) [11], Tadesse *et al.* (2016) [12] and Kumar *et al.* (2019) [8].

Table 3: Correlation coefficient between weed density (m^{-2}) with chickpea seed yield (q ha^{-1})

Character	*Cyprus rotundus* X_2	*Medicago denticulata* X_3	*Vicia sativa* X_4	Total weed X_5	Seed yield (q ha^{-1}) Y
2019-20					
X_1-*Cynodon dactylon*	0.866**	0.950**	0.940**	0.977**	-0.759**
X_2-*Cyprus rotundus*	-	0.853**	0.851**	0.899**	-0.816**
X_3-*Medicago denticulata*	-	-	0.941**	0.982**	-0.737**
X_4-*Vicia sativa*	-	-	-	0.978**	-0.650*
X_5-Total weed	-	-	-	-	-0.745**
2020-21					
Character	**X_2**	**X_3**	**X_4**	**X_5**	**Y**
X_1-*Cynodon dactylon*	0.885**	0.940**	0.933**	0.982**	-0.821**
X_2-*Cyprus rotundus*	-	0.824**	0.839**	0.905**	-0.938**
X_3-*Medicago denticulata*	-	-	0.912**	0.973**	-0.788**
X_4-*Vicia sativa*	-	-	-	0.963**	-0.813**
X_5-Total weed	-	-	-	-	-0.858**
Pooled					
Character	**X_2**	**X_3**	**X_4**	**X_5**	**Y**
X_1-*Cynodon dactylon*	0.877**	0.952**	0.940**	0.981**	-0.805**
X_2-*Cyprus rotundus*	-	0.845**	0.842**	0.901**	-0.911**
X_3-*Medicago denticulata*	-	-	0.938**	0.981**	-0.775**
X_4-*Vicia sativa*	-	-	-	0.974**	-0.749**
X_5-Total weed	-	-	-	-	-0.819**

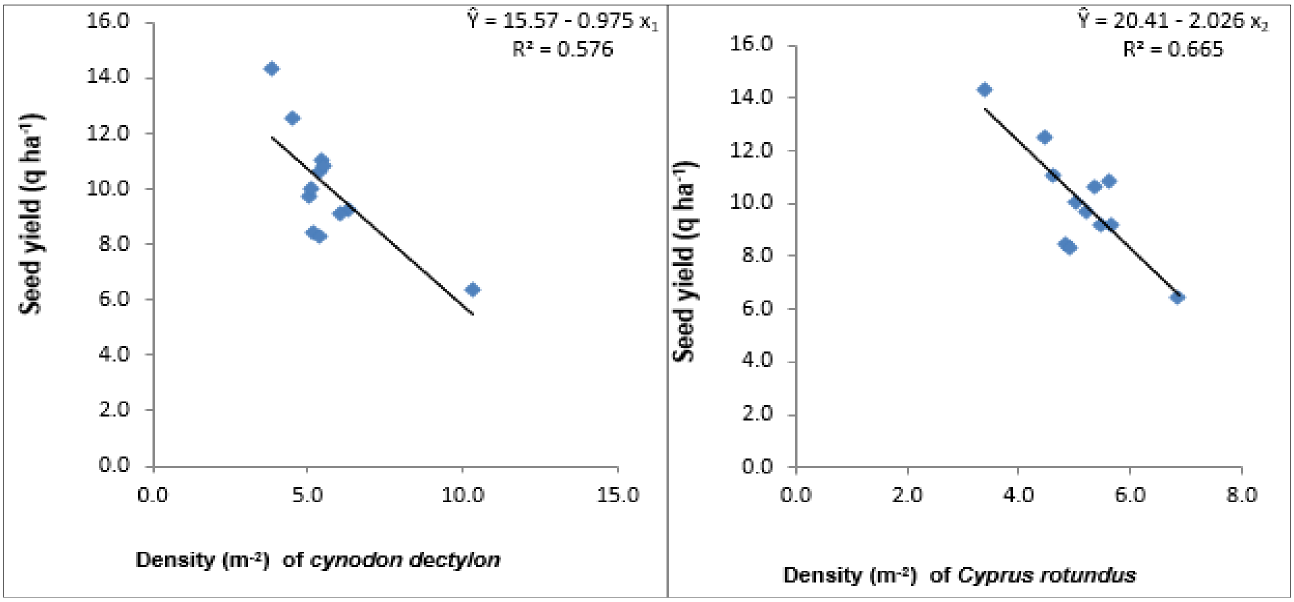
Note:
* -sign indicate significant at 0.05 level of significance.
** -sign indicate significant at 0.01 level of significance.

Regression coefficient between weed density with chickpea seed yield

The regression analysis (Table 4 and Figure 4, 5, 6) revealed that the reduction in chickpea seed yield could be predicted to extent of 2.026 q ha^{-1} with increase of one plant of *Cyprus rotundus.* The greater reduction in yield can also be predicted due to density of *Cynodon dactylon, Medicago denticulate,* and *Vicia sativa.* The reduction could be predicted by 0.975, 0.619 and 0.579 q ha^{-1} respectively during first year (2019-20). However, during second year (2020-21) *Cyprus rotundus* reduced highest extent of chickpea seed yield (2.803 q ha^{-1}) with increase of one plant followed by *Vicia sativa, Cynodon dactylon*, and *Medicago denticulata.* The reduction could be predicted by 1.59, 1.57 and 1.046 q ha^{-1} with increase of one plant of weed species, respectively. The pooled analysis (2019-20 and 2020-21), revealed that reduction in yield could be predicted to the extent 2.466 q ha^{-1} with increase of one plant of *Cyprus rotundus.* The greater reduction in chickpea seed yield can also be predicted due to density of *Cynodon dactylon, Vicia sativa* and *Medicago denticulata.* The reduction could be predicted by 1.254, 0.959 and 0.814 q ha^{-1} with increase of one plant of weed species under gram – Jatropha based Agroforestry system. The similar finding was also reported by Jain and Sharma (2011) [7], Singh *et al.* (2014) [11], Tadesse *et al.* (2016) [12] and Kumar *et al.* (2019) [8].

Table 4: Regression between weed density (m^{-2}) with seed yield (q ha^{-1})

Character	$\hat{Y} = a + bx$	Coefficient of determination (R^2)
2019-20		
X_1-*Cynodon dactylon*	$\hat{Y} = 15.57 - 0.975\ x_1$	0.576
X_2-*Cyprus rotundus*	$\hat{Y} = 20.41 - 2.026\ x_2$	0.665
X_3-*Medicago denticulata*	$\hat{Y} = 14.19 - 0.619\ x_3$	0.543
X_4-*Vicia sativa*	$\hat{Y} = 13.75 - 0.579\ x_4$	0.422
X_5-Total weed	$\hat{Y} = 15.29 - 0.219\ x_5$	0.555
2020-21		
X_1-*Cynodon dactylon*	$\hat{Y} = 20.30 - 1.577\ x_1$	0.673
X_2-*Cyprus rotundus*	$\hat{Y} = 25.21 - 2.803\ x_2$	0.880
X_3-*Medicago denticulata*	$\hat{Y} = 18.20 - 1.046\ x_3$	0.620
X_4-*Vicia sativa*	$\hat{Y} = 21.33 - 1.596\ x_4$	0.660
X_5-Total weed	$\hat{Y} = 21.18 - 0.421\ x_5$	0.736
Pooled		
X_1-*Cynodon dactylon*	$\hat{Y} = 17.85 - 1.254\ x_1$	0.648
X_2-*Cyprus rotundus*	$\hat{Y} = 23.13 - 2.466\ x_2$	0.830
X_3-*Medicago denticulata*	$\hat{Y} = 16.13 - 0.814\ x_3$	0.601
X_4-*Vicia sativa*	$\hat{Y} = 16.84 - 0.959\ x_4$	0.560
X_5-Total weed	$\hat{Y} = 18.02 - 0.308\ x_5$	0.670



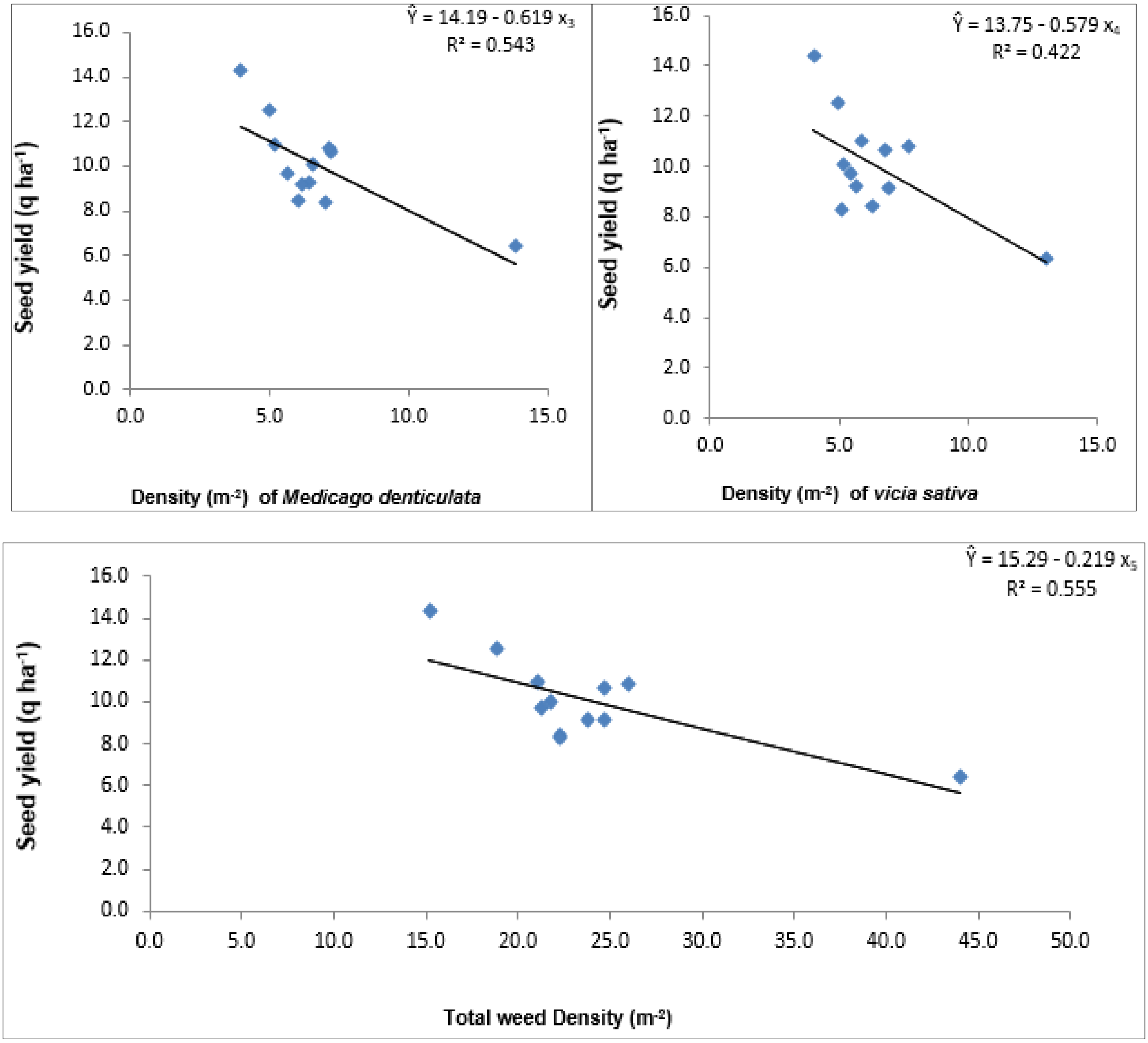
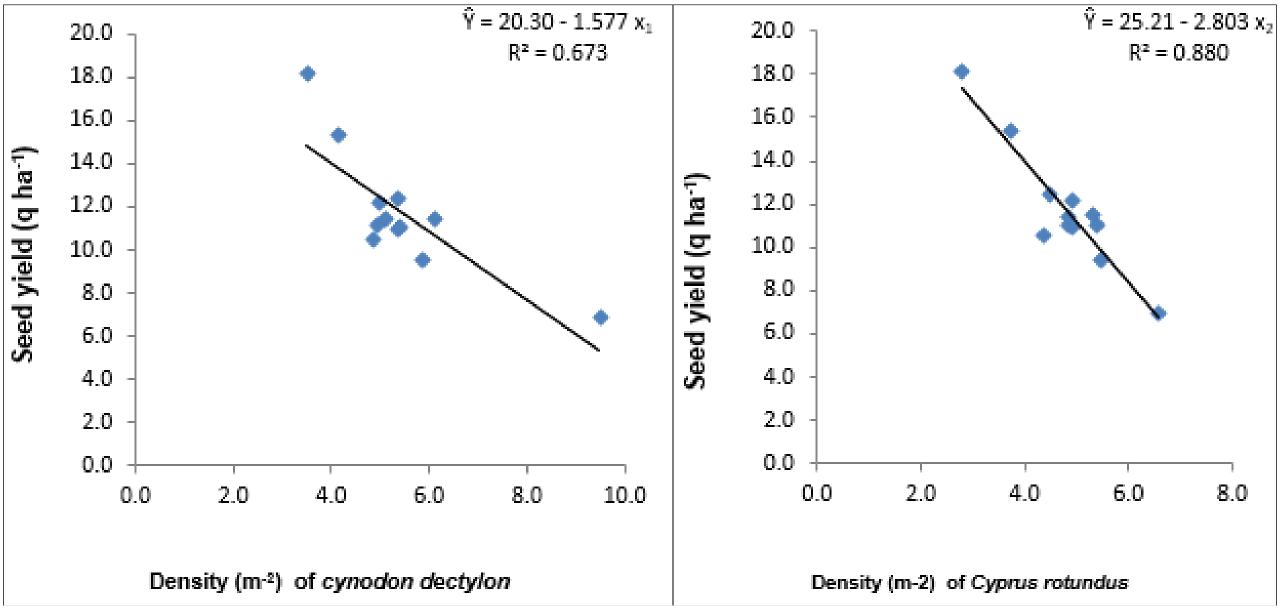


Fig 4: Regression of weed density (m^{-2}) of different species on seed yield (q ha^{-1}) during first year (2019-20)



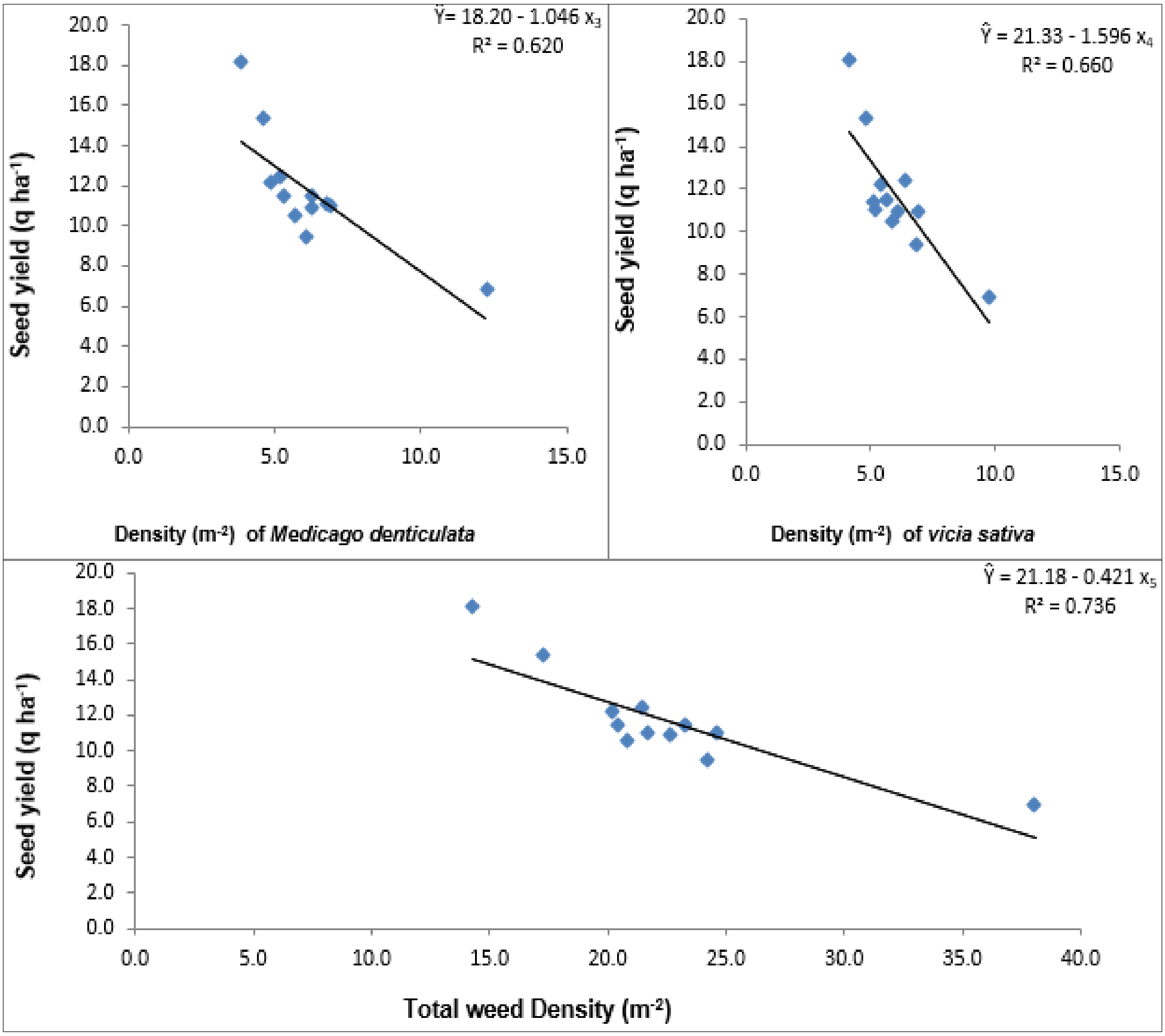
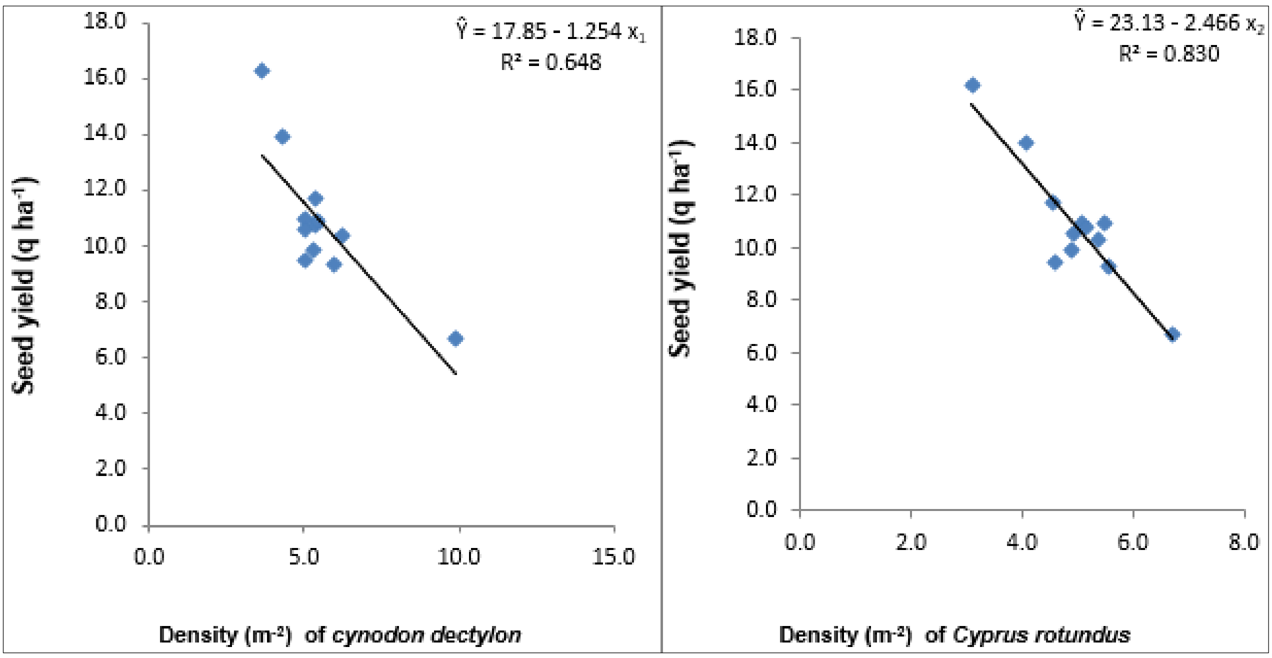


Fig 5: Regression of weed density (m^{-2}) of different species on seed yield (q ha^{-1}) during second year (2020-21)



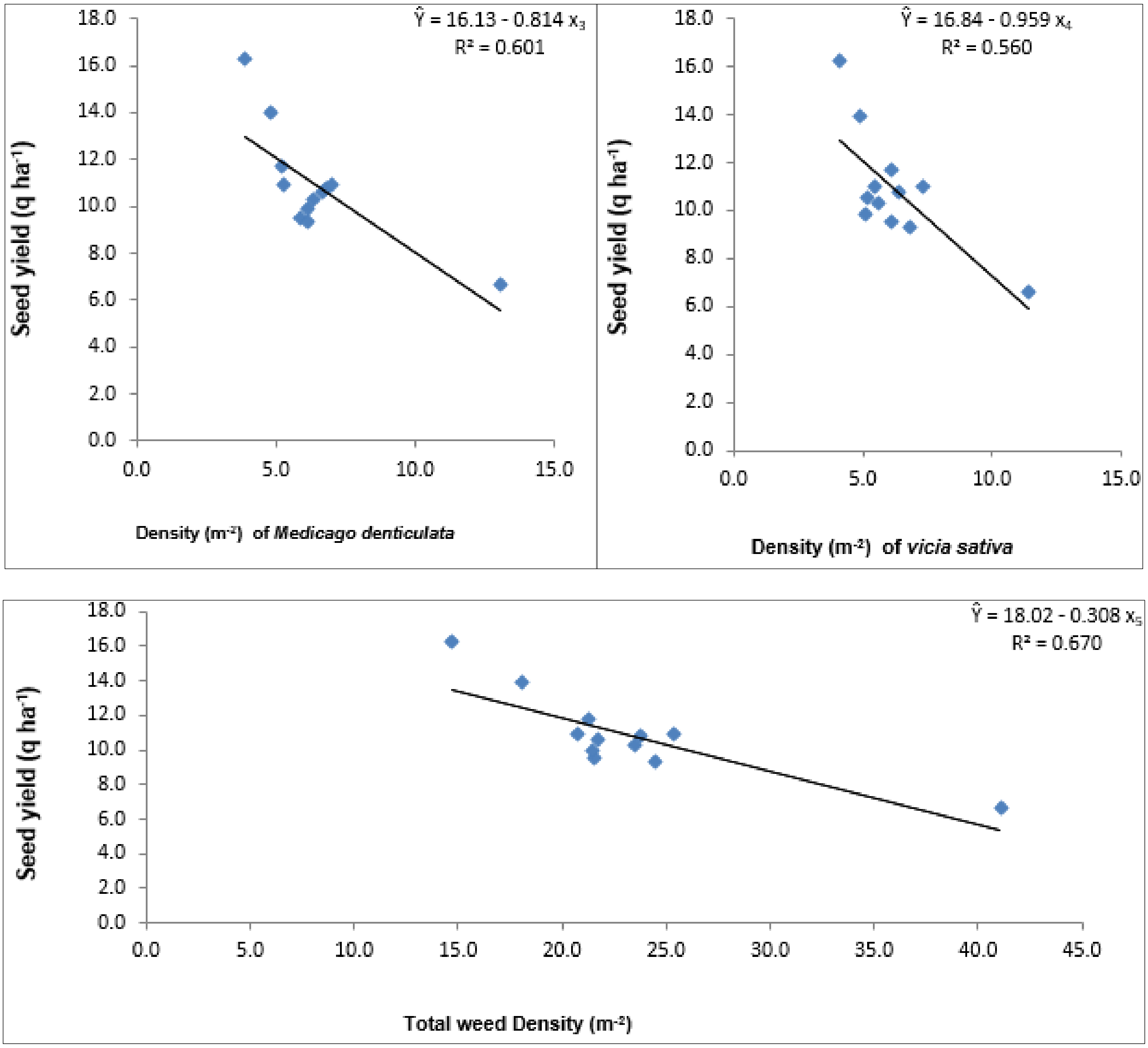


Fig 6: Pooled regression of weed density (m^{-2}) of different species on seed yield (q ha^{-1})

Conclusion

It can be concluded from the Correlation coefficients of *Cyprus rotundus* and *Medicago denticulata* had highest positive correlation with the weed dry weight during both the years. The pooled analysis of *Medicago denticulata* had highest positive correlation with weed dry weight under gram - Jatropha based Agroforestry system. Regression coefficient of *Medicago denticulata* contributed to the greater extent for weed dry weight production with increase of one plant, the increase in weed dry weight could be predicted by *Cyprus rotundus*, *Cynodon dactylon* and *Vicia sativa* during first year and *Cyprus rotundus*, *Vicia sativa*, *Cynodon dactylon* and *Medicago denticulata* during second year. The pooled analysis of *Cyprus rotundus* contributed to the greater extent for weed dry weight production with increase of one plant, the increase in weed dry weight. The correlation Coefficient of *Cyprus rotundus* had highest negative association with seed yield during both the years. The pooled analysis of *Cyprus rotundus* had highest negative correlation with seed yield under gram – Jatropha based Agroforestry. Regression coefficient of the greater reduction in Chickpea seed yield can also be predicted due to density of *Cynodon dactylon, Vicia sativa* and *Medicago denticulata.* The reduction could be predicted with increase of one plant of weed species under gram – Jatropha based Agroforestry system.

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