Evaluation of Yield Advantages, Competitiveness, and Economic Benefits of Pigeonpea(*Cajanus cajan*L.) Based Intercropping Systems Under Different Date of Sowing.

Abstract

A field experiment was conducted to evaluate the yield advantage, competitiveness, and economics of pigeonpea based intercropping system under different dates of sowingat Department of Agronomy farm, VNMKV., Parbhani during *kharif* 2016-2017 and 2017-2018. The soil of experimental plot was deep black (vertisol) with good drainage. The experiment was laid out in split plot design with two replications. In main plot treatment four sowing dates (D_1- sowing within a week period after regular commencement of monsoon, D_2- sowing 15 days after $D_{1,}$ D_3- sowing 15 days after D_2 and D_4- sowing 15 days after D_3) and in sub plot treatments seven cropping system i.e. I_1-pigeonpea+soybean (2:3), I_2- pigeon pea+ pearlmillet (2:1), I_3-pigeonpea+niger (2:3), I_4-sole pigeon pea, I_5- sole soybean, I_6- sole pearlmillet and I_7- sole niger. The net plot size is 5.40 m x 4.80 m for each treatment. The results discover that D_1 date of sowing reported maximum pigeon pea equivalent yield and net monetary return over D_3 and D_4sowing dates but which was on par with D_2. Among seven cropping systems pigeonpea + soybean was marked highest pigeonpea equivalent yield over all other six cropping systems. During pooled result the system net monetary returns affirm that I_1-pigeonpea + soybean cropping system was found significantly superior over cropping systems I_2-pigeonpea + pearlmillet, I_4-sole pigeonpea, I_5-sole soybean,I_6-sole pearlmillet and I_7-sole niger, but which was on par with pigeonpea + niger (I_3). The component crops in intercropping system did not contend equally. The behaviourof niger crop in intercroppingwas found dominant over the pigeonpeabase crop. Pearlmilletand Soybean were the least competitive intercrops while the nigercrop appeared to be muchmore competitive when grown as intercropping in association with a pigeonpeabased cropping system.

~~Key words~~Keywords: Competitiveness, Dates of sowing, economic, Evaluation,Pigeonpea, intercropping systems,Yield advantages

Introduction:

Climate is the most influential factor for crop production. The farmer selects a crop racesa crop race that is adapted to their theregional area where it will be grown. However, it is the weather in the locality that will ultimately determine the crop growth, development, and productivity. Unless the crop and cultivars are well adapted intoa particular area where they are grown, there theircultivation in that locality is uneconomical. Knowledge of agrometeorology and crop physiology is necessary for crop production as it is concerned with the interaction between meteorological, hydrological, and crop phenophases/ physiologicalfactor factorson one hand and crop production on the other.Indian agriculture, to a large extent, depends on the South-WestSouthwest monsoon shower and associated weather phenomenon. Average The averageannual rainfall of the country is about 4 x 103 km^3 (400 M ha m) out of global rainfall of 5 x 105 km^3(Lal, 1994). India's share is only one per centpercent of global precipitation. The 74 % of rainfall contribution is from South West monsoon andthe remaining 10 per centpercent during North EastNorth-East monsoon. The average annual rainfall of the country is 1200 mm (400 M ham). However, distribution across the country varies from Western Rajasthan (< 100 mm),in North Eastern states (> 3600 mm), and 1000 mm from the East Coast to 2500- 3000 mm in the West Coast.

Dryland agriculture has a prominent place in Indian farming, occupying around 67 % of the cultivated area, containing to nearly 44 % of the food basket, and supporting 40 % of the human and 60 % of the livestock population. Most (80 to 90 %) of the pulses, oilseeds, and millets are confined to the dryland ecosystem. It is characterized by resource scarescarcity, small and marginal farmers, poor infrastructure, and low investment in modern technology and proper inputs. The discrepancy between rainfall distribution and the water requirement is the major cause of the instability of certain crops ofindryland areas of India. Most dryland areas of India are either mono-cropped or intercropped. Traditional dryland cropping systems are not necessarily the most suitable ones to forthe agro-climatic conditions as they are mostly subsistence in nature. Crop production in arid and semiarid climateclimates, with < 750 mm annual rainfall, is limited by moderate to severe soil moisture stress during the sustainable period of crop growth season. In arid and semiarid tropics with 4-5 months of crop growing season, the predominant cropping system is intercropping with short seasonshort-season crops. If the cropping growing period is longer (>5-6 months), as in areas of bimodal rainfall distribution, intercropping is mostly taken with long durationlong-duration crop such as pigeonpea and cotton. Although, double cropping with sequential cropping of 3-4 months duration crop can be practiced, farmers prefer intercropping for a number ofseveral reasons. (Rao and Dart, 1987)

Intercropping includes strip cropping,alley cropping, contour cropping, paired row cropping, skip cropping, parallel cropping, companion cropping, multi- storymulti-story cropping, and synergetic cropping in additive and replacement series. Pigeonpea basedPigeonpea-basedintercropping systems with Cereals cerealcrops are more popular in India (Aiyer, 1949). Amount The amountof rainfall determines the cereal crop associated with pigeonpea and rice with 1000 to 1500 mm, maize with 750 to 1000 mm, sorghum with 500 to

750 mm, and millets with 400 ~~t0~~ to600 mm rainfall. Most cereals, depending on their growth and development period, reduce the normal growth of pigeonpea and can be ranked for competitiveness: maize > sorghum >pearlmillet>setaria (Rao and Willey, 1980).

Paired row planting can adjust full population of the base crop and leave adequate ~~inter space~~interspace to accommodate two or more ~~row~~ rowsof intercrop. In this technique two adjacent rows of the base crop are paired by reducing the inter-row spacing in the pair, narrow enough to create some inter-space between pairs of base crop rows but wide enough to minimize competition among plants of the base crop. In the inter-space of 60-120 cm paired rows of pigeonpea, two or more rows of ~~other short statured intercrop~~another short-statured intercrop can be planted. In other words, two rows of base crop and three rows of intercrop can be accommodated in 120 cm (60-120 cm paired) space instead of two rows of base crop alone with the usual planting method. This is often referred to as 60-120 cm paired row planting. In dryland agriculture, intercropping is practiced to minimize the risk of total crop failure due to vagaries in monsoon for yield and economic advantage over sole cropping. Studies in the recent past, however, indicated the profitability of intercropping even under irrigation due to efficient use of natural resources as well as applied inputs. All India coordinated research ~~project~~ projectson cropping systems indicated the productivity of several intercropping systems in different ~~region~~ regionsof the country in the recent past (Hegde, 1992, Singh et al.,1994, Yadav and Prasad, 1997).

Pigeonpea is a highly ~~drought resistant~~drought-resistant crop. It can successfully ~~grown~~ growin areas receiving only 65 cm annual rainfall, as the crop matures fast and pest damage is low. It is mostly photoperiodic sensitive, indeterminate, and short days result in reduced vegetative phase and onset of flowering. Pigeonpea can be cultivated on a variety of soils from sand to heavy clay loams. However, ~~well drained~~well-drained~~medium heavy~~medium-heavy loam soils are best suited. The inbuilt mechanism of biological nitrogen fixation enables pulse crops to meet 30 to 90 % of their nitrogen requirements, hence a small dose of 15- 25 kg N/ha applied at sowing is sufficient to meet the requirement of most of the pulse crops. (Karwasra and Kumar, 2007).Pigeonpea can be knitted into many cropping systems viz., intercropping, mixed cropping ~~and~~ sequential cropping, etc. The initial slow growth, deep rooting pattern, ability to tolerate drought, and low soil moisture ~~has~~ havemade it a highly suitable crop for intercropping systems. It is intercropped with many ~~short duration~~short-duration legumes, cereals, and commercial crops.With the complementary effect of pigeonpea on soil fertility, improvement, nutrient recycling, smothering of weeds and efficient utilization of soil moisture under different cropping systems it occupies more area in cropping systems than as a sole crop.

Materials and methods

The field experiment was conducted during the *kharif*season in 2016 and 2017 at Agronomy~~research~~ResearchFarm, College of Agriculture, Parbhani (Maharashtra). The soil was clayey in texture with a pH 7.80. The soil was low in organic carbon (0.5 %), low in available nitrogen (198 kg/ha), phosphorus (14 kg/ha) and high in potash (492 kg/ha). The experiment consisted of ~~twenty eight~~twenty-eight treatment combinations i.e. 4 dates ofsowing ((D_1- sowing within a ~~week period~~week after regular commencement of monsoon, D_2- sowing 15 days after D_1, D_3- sowing 15 days after D_2 and D_4- sowing 15 days after D_3) and 7 cropping systems i.e. I_1-pigeonpea+soybean (2:3), I_2- pigeon pea+ pearlmillet (2:1), I_3-pigeonpea+niger (2:3), I_4-sole pigeon pea, I_5- sole soybean, I_6- sole pearlmillet and I_7- sole niger in sub-plot. ~~Experiment~~The experimentwas laid out in a split-plot design and replicated twice. The gross (6.60 m x 6.00 m)and net plot size (5.40 m x 4.80 m)~~was~~ weretaken.Pigeonpea variety 'BDN 711', soybean 'MAUS 71', pearlmillet 'ABPC 4-3' ~~and~~ andniger variety 'PNS 6' were sown on 27 June 2016 and 24 June 2017 as first sowing date (D_1) and D_2, D_3 and D_4 sowing ~~was~~ weredone after 15 days interval between each sowing date in both the yearrespectively. The seeds were sown in 60 cm x 20 cm spacing for sole pigeonpea, 30 cm x 15 cm for sole soybean and sole niger, and 60 cm x 15 cm for sole pearlmillet. In the intercrop situation, pigeonpea was sown in paired rows at 60 cm keeping a 120 cm distance between 2 pair to adjust 3 rows of intercrop for soybean and niger (2:3) and 1 row (2:1) for pearlmillet (60/120 cm). The plant-to-plant distance of 20 cm in pigeonpea and 15 cm in intercrops was maintained. The recommended seed rates of 12-15 kg ha^{-1}, 60-65 kg ha^{-1}, 4-5 kg ha^{-1}, and 3-4 kg ha^{-1} of pigeonpea, soybean, pearlmillet, and niger for sole and intercrops, respectively, were used in the experiment. The recommended dose of 25 kg N/ha through urea and 50 kg P_2O_5/ha through single superphosphate was applied to sole pigeonpea as well as in intercrops. Also the recommended dose of 30:60:30 NPK kg ha^{-1} for soybean, RDF 60:30:30 NPK kg $ha^{-1}$for pearlmillet and RDF 20:20:0 NPK kg ha^{-1} for niger crop through urea, SSP, and MOP were drilled before sowing as a basal application. To maintain a healthy and good crop stand follow the all recommended package of practices like ~~thining~~thinning, weeding, and plant protection measures as and when required.

The yield advantages of different intercropping systems over sole pigeonpea were determined in terms of pigeonpea crop equivalent (CEY), land equivalent ratio (LER) area time equivalent ratio (ATER), Aggressivity, Relative crowding coefficient (RCC), Competition Index (CI), Competition ratio (CR) and Competition coefficient (CC).

PigeonpeaCrop EquivalentYield(CEY)

~~Onthebasisof~~Based onGovt.the minimumsupportprices(MSP)ofpigeonpea, soybean, pearlmillet,andnigerseed theyieldofeachtreatmentforbothcomponentcropsconverted intocropequivalentyieldofpigeonpeacrop(Anjeneyula et al., 1982).Thepigeonpeaequivalentyield(PEY)(kgha^{-1})iscalculatedasfollows:

$$PEY = . \sum_{i=0}^{n} Yi \quad ei$$

Where,

Yiistheyieldofi~~th~~thecomponent

eiisan equivalentfactorofithcomponentofpricei~~th~~thecrop or

$$PEY = P_{ab} + \frac{N_{ab} \times N_{mp}}{P_{mp}}$$

Where,

PEY =Pigeonpeaequivalentyield(kgha^{-1})

Pab =Yieldofpigeonpeainthe intercroppingsystem(kg ha^{-1})

Nab=Yieldof soybean, pearlmillet, and nigerinthe intercroppingsystem(kgha^{-1})

Nmp= Soybean, pearlmillet and Nigermarketprice(kg ha^{-1})

Pm= Pigeonpeamarketprice(kg ha^{-1})

LandEquivalentRatio(LER)

~~Land~~The landequivalentratioisdefinedastherelativelandareaundera solecropthatisrequiredtoproduce~~the~~anequalamountofyieldfromthe intercropping systemunderthe samemanagementlevel.TheLERwasworkedoutbyusingthe formulaofWilley(1979).

Forstudyingthebestutilizationofland,thelandequivalentratiofor varioustreatmentswascalculatedbyusingthegivenformula.

$$LER = \sum_{i=1}^{m} \frac{Yj}{Yij}$$

Where,

$Y_i$istheyieldofithcomponentfromaunitareagrownasintercrop

Y_{ij}istheyieldofithcomponentgrownasasolecropoverthesamearea.

Inbrief,LER isthesummationofratiosofyieldsofintercroptotheyieldofsolecrop.

Or

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where,

Yab = Yield of ‘a’ component intercropped with ‘b’

Yaa = Yield of ‘a’ component in sole planting

Yba = Yield of ‘b’ component intercropped with ‘a’

Ybb = Yield of ‘b’ component in sole planting

Area time equivalent ratio

TheLERmethodwasmodifiedbyHiebschandMcCollum(1987)to includethedurationofthecroppresentonthelandfromplantingtoharvest.This methodisknownastheareatimeequivalentratio(ATER).

$$\text{ATER} = \frac{Y_p D_p + Y_n D_n}{T_d}$$

Where,

Yp	=	Yieldofpigeonpea(kgha^{-1})
Yn	=	Yieldof soybean, pearlmillet and niger(kgha^{-1})
Dp	=	Durationofpigeonpea
Dn	=	Durationof soybean, pearlmilletand niger
Td	=	Total duration of crop

Or

Area time equivalent ratio was calculated by using the following formula suggested by Mendhe*et al.* (2007).

$$\text{ATER} = \frac{1}{ti} = \sum_{1}^{n} \left(\frac{d \; - \; Yi}{Ym} \right)$$

Where,

d	=	Growth period of crops in days
t	=	Time in days for which the field remained occupied (i.e. the growth period of the ~~longest duration~~longest-duration crop)
Yi	=	Yields of component crops in the ~~inter cropping~~inter-cropping system
Ym	=	Yield of component crops in monoculture cropping system
n	=	Number of crops involved

Aggressivity

This method was proposed by Mc Gilchrist (1965). It is the mixture of how much the relative yield increase in component a crop is greater than that for component b crop.

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Where,

Yab	=	Yield of ‘a’ component intercropped with ‘b’
Yaa	=	Yield of ‘a’ component in sole planting
Yba	=	Yield of ‘b’ component intercropped with ‘a’
Zab	=	Row proportion of ‘a’ component intercropped in ‘b’
Zba	=	Row proportion of ‘b’ component intercropped in ‘a’
Ybb	=	Yield of ‘b’ component in sole planting

A_{ab} = Negative means get dominated

A_{ab} = Bigger value either positive or negative means bigger difference in competitive abilities

Aab = 0 (component crops are equally competitive)

Aab = <0 (component a crop dominated)

Aab = >0 (component a crop dominant)

Relative crowding coefficient (RCC):

It was proposed by Dewit (1960). It is used in replacement series of intercropping. It indicates whether a species or crops, when grown in mixed population, has produced more or less yield than expected in pure stand.

In 50:50 mixture

$$\text{Kab (RCC)} = \frac{\text{Mix. Yield of a}}{\text{Pure stand yield of a} - \text{Mix. Yield of a}}$$

$$\text{Kab} = \frac{Y_{ab}}{Y_{aa} \times \text{Yab}}$$

$$\text{For all mixture :Kab} = \frac{\text{Yab X zba}}{(\text{Yaa} - \text{Yab})\ \text{Zab}}$$

Where

Yab= mix. yield of a crop grown with b

Yaa= yield of pure stand crop a

Zab= proportion of sown spp. a in mix. With b

Zba= proportion of sown spp. b in mix. With a

K > 1 Yield advantage

K = 1 No difference

K < 1 Yield disadvantage

Competition Index (CI):

It is a measure to find out the yield of various crops when grown together as well as separately.It was proposed by Donald (1963)

$$\text{CI} = \frac{(\text{Yaa} - \text{Yab}) \text{ X } (\text{Ybb} - \text{Yba})}{\text{Yaa X Ybb}}$$

Competition ratio (CR)

Competition ratio is measure of intercrop competition, to indicate number of times by which the component crop is more competitive with than the other. The CR values for different replacement treatments were calculated by the equation given by Willey and Rao, 1980.

$$\text{Cra} = \frac{\text{Yab}}{\text{Yaa x Zab}} \div \frac{\text{Yba}}{\text{Ybb x Zba}}$$

Cra = Competition ratio for component ‘a’

Zab = Row proportion of ‘a’ component intercropped in ‘b’

Zba = Row proportion of 'b' component intercropped in 'a'

Statistical analysis and interpretation of data

The experimental data obtained on various selected variables were analyzed by the standard method of statistical analysis (Panse and Sukhatme, 1967) for split plot design. The mean values of different treatments were then worked out along with corresponding standard error of mean (SEm). The critical difference at 5 per cent level of significance was computed by the formula.

CD = SEm x √2 x t value at respective d.f.

Results obtained have been presented in the form of summary tables, providing SEm in each case and CD at 5 per cent level wherever significant. The values of CD have been taken into account for drawing conclusionsconcluding.

Results and discussion

Thedataregardingtheassessmentofyieldadvantageofintercroppingsystemviz.pigeonpea equivalent yield(PEY),landequivalentratio(LER), Aggressivity, Area time equivalent ratio (ATER), relative crowding coefficient (RCC), competition index (CI) competition ratio (CR) and net monitory return (NMR)of pigeonpeainfluencedbysowing dates and different cropping systems treatments were presentedinTable1.

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Sowing dates

Sowing date(D_1) was found significantly superior for system pigeonpea equivalent yield (1661 kg ha^{-1}) than other sowing dates (D_3 and D_4) during both the years and it was at par with D_2 (1508 kg ha^{-1}) in pooled analysis.

The land equivalent ratio was significantly influenced due to sowing dates during both the years. Third sowing date (D_3) in pigeonpearecorded higher land equivalent ratio (1.19) as compared D_1, D_2 and D_4 sowing date, during first year. In the second year fourth sowing date (D_4) recorded higher LER (1.33) than other sowing dates. These results are in conformityconform with those reported by Pramila Rani and Raji Reddy, (2010), Hari Ram *et al*., (2011) and Channabasavanna*et al*., (2015).

ATER during the year 2016-17 was observed higher in sowing dates D_3(1.05).In next year it was found in sowing dates D_4 (1.13)but less difference were seen between all sowing dates. ATER is the ratio of the sum of yield of main crops and yield of component crop multiplied with bythe duration of both crops to the total duration (days) of intercropping system. Delayed sowing reduces their crop duration also utilize utilizestime effectively as compared to early sowing dates.

Aggressivity The aggressivityof sowing date D_4 was found higher (0.55) during first year. In next year it was seen in sowing dates D_3 (0.51). Aggressivity (Aab) was greater than (> 0) means all the sowing dates had difference in competitive ability.This might be due to delayed sowing increases the competition for soil moisture, nutrients, space and PAR within plant to plant and between two intercrops. (Patil, 2003, Dandayuthapani and Kuzhanthaivel, 2015)

Relative crowding coefficient of sowing date D_2 (1.51) was confirmed higher during 2016-17 and it was found higher in sowing date D_1 (2.28) during 2017-18. As RCC i.e. K value was greater than one (> 1) means more yield advantages than other sowing dates. As it was depends upon the row proportion of crops and yield of both the crops.

Competition index and Competition ratio during both the year of experimentation were observed in sowing dates D_4 i.e. 0.46, 2.03 and 0.40, 1.80 respectively except CR was seen higher in sowing dates D_3 (1.80) during next year. CI measures the yield of various crops when grown together as well as separately. Here CR was the ratio of individuals LER'S of the two component crops, corrected by multiplying with their sowing proportion.

The system net monetary returns were significantly influenced due to sowing dates during pooled analysis. First sowing date (D_1) in pigeonpea observed significantly higher net monetary returns (Rs. 43275 ha^{-1}) as compared D_2, D_3 and D_4 sowing date, during pooled analysis. A lowest system net monetary return was seen in sowing date D_4(Rs.1817 ha^{-1}).Islam *et al*. (2008) also obtained higher net returns in early sown crop of pigeonpea.

Cropping systems

The different cropping systems markedly influenced the indices of intercropping system viz. pigeonpea equivalent yield (PEY), land equivalent ratio (LER), Aggressivity, Area time equivalent ratio (ATER), relative crowding coefficient (RCC), competition index (CI) competition ratio (CR) and net monitory return (NMR) of pigeonpeawere depicted in Table 1.

Total pigeonpea equivalent yield (PEY) is the best tool to determine the overall productivity potential of an intercropping system. The data presented in Table 1reflected that Systempigeonpea equivalent yield of pigeonpea + soybean (I_1) found superior i.e.1958 kg ha^{-1} over pigeonpea + pearlmillet (I_2), pigeonpea + niger (I_3), Sole soybean(I_5), sole pearlmillet (I_6) and sole niger (I_7), but it was on par with sole pigeonpea (I_4) during pooled analysis.Pigeonpea equivalent yield (PEY) of intercropping system was recorded significantly higher except pigeonpea + pearlmillet (I_2), pigeonpea + niger (I_3) than sole pigeonpea system because of higher yield of both crops and more or less remunerative prices of intercrop than sole cropping system. The differential behavior in PEY was on account of productivity of crops in intercropping system and their relative market prices (Rathod *et al*.,2004a).

The land equivalent ratio (LER) is the relative area of a sole crop required to produce the yield achieved in intercropping. If LER value is equal to one, it means that there is no yield advantage but when LER is more than one, then there is yield advantage. The data on LER of different intercropping systems indicated thatLER of cropping system pigeonpea + pearlmillet (I_2) (1.28 and 1.39) recorded maximum during 2016-17 and 2017-18 as compared to all other cropping systems. It means 28 % and 39 % more area or yield required to sole crops to obtain similar yield when grown in intercropping. Lowest LER obtained in all sole cropping systems.(Gare *et al.*,2004 and Yenebala, 2017)

As the LER not take into account the time for which land is occupied by the component crops of an intercropping system, area-time equivalent ratio (ATER) was also calculated. The ATER provides a more realistic comparison of the yield advantage of intercropping over that of the sole cropping that the LER as it considers variation in time taken by the component crops of different intercropping systems. The ATER values shown in Table 1 revealed that ATER in all the intercropping systems was smaller thanLER values indicating the over estimation of resource utilization in the latter. Hence contrary to LER, the ATER is free from the prediction of over estimation of resources utilization. Based on two year data, ATER value of pigeonpea + pearlmillet (I_2) (1.15 and 1.25) cropping system was found higher during both the year of research investigation. It confirmed that pigeonpea + pearlmillet (I_2) cropping system utilize area very efficiently as well as time also as compared to other systems. Lowest ATER was seen in pigeonpea + niger (I_3) (0.84 and 0.81) cropping system.Higher ATER values in the above mentioned intercropped treatments were due to higher combined seed yield per plant of both the crops per unit area and longer duration of the crop present on the land from planting to harvest. (Dandayuthapani and Kuzhanthaivel, 2015, Yenebala, 2017)

Competition functions

Competitive behavior of the component crops across different intercropping systems was determined in terms of aggressivity, relative crowding coefficient, competition index and Competition ratio.

Aggressivity is an important competition function to determine the competitive ability of a crop when grown in association with another crop. An aggressivity value of zero indicated that component crops are equally competitive. For another situation, both crops will have the same numerical value but the sign of the dominant species will be 'positive' and that of dominated 'negative'. The greater the numerical value, the higher is the difference in competitive abilities and the higher the differences between actual and expected yields. The data shown in Table 1 revealed thataggressivity of pigeonpea + niger (I_3) cropping system (-0.50) was recorded negative value during first year. It means component crop show dominant effect on main crop. During second year pigeonpea + niger (I_3) was recorded not negative value (0.08) but near to 0 i.e. aggressivity = 0 that component crop (Niger) was equally competitive to main crop. Here pigeonpea + soybean (I_1) and pigeonpea + pearlmillet (I_2) cropping systems recorded aggressivity value more than 0; both the systems had different in competitive ability. These indices decide the suitability of intercropping systems for cultivation.Similar findings was confirmed by Yenebala, 2017)

Relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping. According to Willey (1979), in an intercropping system, each crop has its own RCC (K). The component crop with higher "K" value is the dominant and that with low "K" value is dominated. To determine if there is a yield advantage in intercropping, the product of the coefficient of both component crops is obtained and that is usually designated as "K". If the product of RCC of the two species is equal, less or greater than one it means that the intercropping system has no advantage, disadvantage or advantage, respectively.RCC during both the year (2016-17 and 2017-18) confirmed greater in pigeonpea + soybean (I_1) i.e. 2.40 and 2.52, cropping system. As RCC value was greater than 1 means yield advantages over sole crops. Lower RCC was obtained in pigeonpea +

niger (I_3) (0.74) cropping system means K <1 yield disadvantage confirmed over other treatments during first year. In second year it was slightly more than 1in pigeonpea + niger (I_3) (1.12) cropping system i.e. RCC/ K = 1 no difference in yield of both the crops over rest of the systems.

Competition index (CI)) during 2016-17 year of experimentation was observed in pigeonpea + soybean (I_1) i.e. 0.10 cropping system. In next year pigeonpea + niger(I_3) i.e. 0.09, was recorded lower CI. CI is the ratio of yield difference of both the crops grown in sole and intercropping to the sole yield of both the crops. As it measures the yield of various crops when grown together as well as separately. It indicates suitability of crops under intercropping.

Competition ratio (CR) is another way to know the degree with which one crop competes with the intercrop.Competition ratio (CR) during both the year of experimentation was observed in pigeonpea + soybean (I_1)(3.01 and 2.59) system. CR was the ratio of individuals LER'S of the two component crops, corrected by multiplying with their sowing proportion.

Economic analysis

Economic analysis is essential as the farmers are often interested in profits and costs of a newly evolved technology. They also like to know about risks involved in the adoption of new practices**.** The data revealed thatsystem net monetary returns of pigeonpea + soybean (I_1) found maximum Rs. 54,449 ha^{-1}over pigeonpea + pearlmillet (I_2), pigeonpea + niger (I_3), sole pigeonpea (I_4), Sole soybean(I_5), sole pearlmillet (I_6) and sole niger (I_7) during pooled analysis. Negative values of net monetary returns were confirmed in sole soybean I_5), sole pearlmillet (I_6) and in sole niger (I_7) during pooled analysis.

The candidate manuscript does not have a robust scientific discussion, I suggest the authors incorporate the suggested paragraphs, in this way, it would improve the scientific quality of the manuscript:

In the dynamic agricultural landscape of tropical environments in Latin America, optimizing crop management practices is essential for sustainable food production and economic stability. The study evaluating pigeonpea (*Cajanus Cajan* L.) based intercropping systems under different dates of sowing addresses critical gaps in our understanding of agro-environmental factors (Bertorelli and Olivares, 2020; Hernandez et al. 2018c), climate variability (Campos, 2023; Olivares, 2023), soil dynamics(Olivares, 2022; Olivares et al. 2022), and agronomic management practices specific to the region(Olivares et al. 2016a; 2016b; Camacho et al. 2018).

The experiment conducted at the Department of Agronomy farm, VNMKV., Parbhani, during the kharif seasons of 2016-2017 and 2017-2018, integrates key agro-environmental factors. The utilization of deep black (vertisol) soil with good drainage replicates prevalent soil conditions in the region, ensuring the relevance and applicability of the findings to tropical environments of Latin America(Hernandez et al. 2018a; 2018b). The implementation of a split plot design with two replications, considering four sowing dates and seven cropping systems, enhances the experimental robustness, facilitating a comprehensive evaluation of the interactions between timing and cropping systems(Cortez et al. 2019; Hernandez et al. 2017).

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The study's findings highlight the significance of sowing dates in maximizing pigeonpea equivalent yield and net monetary returns, with sowing within a week period after the regular commencement of the monsoon (D1) demonstrating superior performance. Furthermore, the pigeonpea + soybean intercropping system emerges as the most favorable(Zingaretti and Olivares, 2018), indicating its potential for enhancing agricultural productivity and economic returns in the region(Hernandez and Olivares, 2019; Hernandez et al. 2020).

The study's insights into the competitiveness and economic benefits of different intercropping systems provide valuable guidance for agronomic management practices in tropical environments(Zingaretti and Olivares, 2019). By identifying the superior performance of certain cropping systems, such as pigeonpea + soybean, and the influence of sowing dates on yield outcomes(Zingaretti et al. 2017; Viloria et al. 2023), the study informs farmers and agricultural practitioners on optimal strategies for maximizing productivity and profitability in pigeonpea cultivation(Montenegro et al. 2021a; 2021b).

The observed behavior of component crops within intercropping systems underscores the complexity of crop interactions and highlights the need for tailored management approaches. The dominance of the niger crop in intercropping systems over the pigeonpea base crop emphasizes the importance of understanding crop dynamics for optimizing yield outcomes(Cortez et al. 2016b; Hernandez and Olivares, 2020). Additionally, the study's evaluation of different sowing dates contributes to enhancing climate resilience(Guevara et al. 2012b) in agricultural systems by identifying optimal timing strategies for mitigating climate variability effects on crop performance(Cortez et al. 2018; Parra et al. 2013; Guevara et al. 2012a).

Conclusion

In conclusion, this study significantly contributes to advancing our understanding of agro-environmental factors, climate variability, soil dynamics, and agronomic management practices in tropical environments of Latin America(Parra et al. 2012; Parra et al. 2017). By evaluating pigeonpea-based intercropping systems under different dates of sowing, the study provides actionable insights for enhancing agricultural productivity, economic benefits, and climate resilience in the region(Parra et al. 2018; Olivares et al. 2015). The findings have immediate implications for informing agronomic management decisions and guiding sustainable agricultural practices tailored to the specific challenges and opportunities of tropical environments in Latin America(Cortez et al. 2016a; Olivares et al. 2016; Olivares, 2018).

References

Aiyer A.K.Y.N. 1949. Mixed cropping in India. *Ind. J. Agric. Sci.***19**:39-443

Anjeneyulo, V.R., S.P. Singh and M. Paul. 1982. Effect of competition free period and techniques and patterns of pearl millet planting on growth and yield of mungbean intercropping system. Indian J. Agron. 27(23): 219-226.

Bertorelli, M., & B.O. Olivares. (2020). Population fluctuation of Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) in sorghum cultivation in Southern Anzoategui, Venezuela. Journal of Agriculture University of Puerto Rico, 104(1):1-16. https://doi.org/10.46429/jaupr.v104i1.18283

Camacho, R., Olivares, B.,Avendaño, N. (2018). Agri-food landscapes: an analysis of the livelihoods of indigenous Venezuelans. Revista de Investigación. 42(93):130-153. https://n9.cl/9utqc

Campos, B.O. Fusarium Wilt of Bananas: A Threat to the Banana Production Systems in Venezuela. In: Banana Production in Venezuela. The Latin American Studies Book Series. Springer, Cham. 2023, https://doi.org/10.1007/978-3-031-34475-6_3

Channabasavanna, A. S., M. S. Kitturmath and H. Rajakumar. 2015. Standardization of sowing date and genotypes of pigeonpea [*Cajanus cajan*(L.) Millsp.] under erratic rainfall conditions in northern dry zone of Karnataka. *Karnataka J. Agric. Sci.* 28(4):604-605.

Cortez, A., Olivares, B., Lobo, D., Parra, R., Rey, J.C. y Rodríguez, M.F. (2016b). Study of Meteorological Drought in the Venezuelan Plains using the Standardized Precipitation Index. Revista Acta Nova. 7 (3):266-283. http://www.scielo.org.bo/pdf/ran/v7n3/v7n3_a04.pdf

Cortez, A., Olivares, B., Parra, M., Lobo, D., Rey, JC., Rodriguez, MF. (2019). Systematization of the Standardized Precipitation Index calculation as a methodology to generate meteorological drought information. Rev. Fac. Agron. (LUZ). 36(2):209-223. https://n9.cl/4spjp

Cortez, A., Olivares, B., Parra, R., Lobo, D., Rodríguez, M.F. y Rey, J.C. (2018). Description of meteorological drought events in localities of the central mountain range, Venezuela.Ciencia, Ingenierías y Aplicaciones. I (1):22-44. DOI: http://dx.doi.org/10.22206/cyap.2018.vlil.pp23-45.

Cortez, A., Rodríguez, M.F., Rey, J.C., Ovalles, F., González, W., Parra, R., Olivares, B., Marquina, J. (2016a). Space-time variability of precipitation in Guárico state, Venezuela. Rev. Fac. Agron. (LUZ) 33 (3): 292-310. https://n9.cl/pmdck

De Wit, C.T. 1960. On competition. Versl. Landbouwk, Onderzoek 66(8): 1-82.

Dhandayuthapani, U. N., and R. L. Kuzhanthaive. 2015. Analysis of light transmission ratio and yield advantages of pigeonpea in relation to intercrop and different plant population. *Afr. J. Agric. Res.* 10(8):731-736.

Donald, C. M. 1963.Competition among crop and pasture plants. *Advances in Agronomy*.**10**: 435-473.

Gare, B. N., S. M.More, M. G. Jadhav and A. V. Burli. 2004.Effect of pigeonpeaand sorghum intercrop on yield of soybean under rainfed condition in Sub- Montane Zone of Maharashtra. *JournalofMaharashtra Agric. Univ.* **29**(2):170-172.

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Guevara, E. Olivares, B., Demey, J. (2012a) The Use of Climate Biomarkers in Agricultural Production Systems, Anzoategui, Venezuela. RevistaMulticiencias. 12 (2): 136-145. https://n9.cl/ak22r

Guevara, E., Olivares, B., Demey, J. (2012b). Use of and Demand for Agrometeorological Information in Agricultural Production Systems, State of Anzoátegui, Venezuela. RevistaMulticiencias. 12 (4): 372-381. https://n9.cl/yuyd

Hari, R., G. Singh, H.S. Sekhon and Veena Khanna. 2011. Effect of sowing time on the performance of pigeonpea genotypes. *J. Food Leg.* 24(3): 207-210.

Hegde, D. M. 1992. Cropping systems research highlights. Bulletin PDCSR, Modipuram, Meerut, India.

Hernández, R. & Olivares, B. (2019). Ecoterritorial sectorization for the sustainable agricultural production of potato (Solanum tuberosum L.) in Carabobo, Venezuela. Agricultural Science and Technology. 20(2): 339-354. https://doi.org/10.21930/rcta.vol20_num2_art:1462

Hernández, R., Olivares, B. (2020). Application of multivariate techniques in the agricultural land's aptitude in Carabobo, Venezuela. Tropical and Subtropical Agroecosystems, 23(2):1-12. https://n9.cl/zeedh

Hernandez, R.; Olivares, B.; Arias, A; Molina, JC., Pereira, Y. (2020). Eco-territorialadaptabilityoftomatocrops for sustainableagriculturalproduction in Carabobo, Venezuela. Idesia, 38(2):95-102. http://dx.doi.org/10.4067/S0718-34292020000200095

Hernández, R; Olivares, B. Arias, A; Molina, JC., Pereira, Y. (2018a). Agroclimatic zoning of corn crop for sustainable agricultural production in Carabobo, Venezuela. RevistaUniversitaria de Geografía.,. 27 (2): 139-159. https://n9.cl/l2m83

Hernández, R; Olivares, B., Arias, A; Molina, JC., Pereira, Y. (2018b). Identification of potential agroclimatic zones for the production of onion (Allium cepa L.) in Carabobo, Venezuela. Journal of the Selva Andina Biosphere., 6 (2): 70-82. http://www.scielo.org.bo/pdf/jsab/v6n2/v6n2_a03.pdf

Hernández, R; Olivares, B., Coelho, R., Molina, JC., Pereira, Y. (2018c). Spatial analysis of the water index: an advance in the adoption of sustainable decisions in the agricultural territories of Carabobo, Venezuela. Revista Geográfica de América Central. 60 (1): 277-299. DOI: https://doi.org/10.15359/rgac.60-1.10

Hernández, R; Pereira, Y; Molina, JC; Coelho, R; Olivares, B y Rodríguez, K. (2017). Calendario de siembra para las zonas agrícolas del estado Carabobo enla República Bolivariana de Venezuela. Sevilla, Spain, Editorial Universidad Internacional de Andalucía. 247 p. https://n9.cl/sjbvk

Hiebsch, C.K. and R.E. McCollum.1987.Areatime equivalent ratio: A method of evaluating the productivity of intercrops. *Agron. J.* **79**:15-22.

Islam, S., Nanda, M. K. and A. K. Mukherjee. 2008. Effect of date of sowing and spacing on growth and yield of *rabi* pigeonpea [*Cajanus cajan*(L.) Millsp.]. *J. Crop and Weed*. 4(1): 7-9.

Karwasra, R. S. and Kumar. 2007. Response of pigeonpea (Cajanus cajan L.) to NPK in Haryana. *Haryana J.Agron.***23** (1/2): 117

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Lal, R. 1994. Water management in various crop production systems related to tillage. *Soil and Tillage Res.* **30**: 169-185.

McGillchrist, I.A. 1965. Analysis of competition experiments. Biometrics 21: 975-985.

Mendhe, S.N., W.S. Pawar and S.R. Ghadekar 2007. Sustainable agriculture. Farming Systems and Sustainable Agriculture: 95.

Montenegro, E; Pitti, J; Olivares, B. (2021a). Adaptation to climate change in indigenous food systems of the Teribe in Panama: a training based on CRISTAL 2.0. Luna Azul. 51 - 2, pp. 182 - 197. https://n9.cl/qwvwz.

Montenegro, E; Pitti, J; Olivares, B. (2021b). Identification of the main subsistence crops of Teribe: a case study based on multivariate techniques. Idesia. 39 - 3, pp. 83 - 94. http://dx.doi.org/10.4067/S0718-34292021000300083

Olivares B, Vega A, Calderón MAR, Rey JC, Lobo D, Gómez JA, Landa BB. (2022). Identification of Soil Properties Associated with the Incidence of Banana Wilt Using Supervised Methods. Plants, 11(15):2070. https://doi.org/10.3390/plants11152070

Olivares B. (2022). Machine Learning and the New Sustainable Agriculture: Applications in Banana Production Systems of Venezuela. Agricultural Research Updates. 42, 133 - 157.

Olivares, B. 2018. Tropical conditions of seasonal rain in the dry-land agriculture of Carabobo, Venezuela. La Granja: Journal of Life Sciences. 27(1):86-102. http://doi.org/10.17163/lgr.n27.2018.07

Olivares, B., Cortez, A., Muñetones, A. y Casana, S. 2016a. Strategic Elements of Organizational Knowledge Management for Innovation. Case: Agrometeorology Network. Revista Digital de Investigación en Docencia Universitaria. 10 (1): 68-81. http://dx.doi.org/10.19083/ridu.10.446

Olivares, B., Cortez, A., Rodríguez, M.F, Rey, J.C. y Lobo, D. 2016b. Development of the information system of the network of alternative rain gauges in rural areas. Case: Anzoátegui, Venezuela. Acta Universitaria 26 (4):65-76. DOI: 10.15174/au.2016.961

Olivares, B., Rodríguez, M.F, Cortez, A., Rey, J.C., Lobo, D. (2015). Physical Natural Characterization of Indigenous Community Kashaama for Sustainable Land Management. Acta Nova. 7 (2):143-164. https://n9.cl/6gezo

Olivares, B., Zingaretti, M.L., Demey Zambrano, J.A., Demey, J.R. (2016). Typification of agricultural production systems and the perception of climatic variability in Anzoátegui, Venezuela. Revista FAVE - CienciasAgrarias 15 (2): 39-50. https://doi.org/10.14409/fa.v15i2.6587

Olivares, B.O. Evaluation of the Incidence of Banana Wilt and its Relationship with Soil Properties. In: Banana Production in Venezuela. The Latin American Studies Book Series. Springer, Cham. 2023, https://doi.org/10.1007/978-3-031-34475-6_4

Panse, V.G. and P.V. Sukhatme. 1967. Statistical methods for agricultural workers. ICAR, New Delhi. pp. 381.

Parra, R, Olivares, B., Cortez, A. 2017. Characterization of precipitation patterns in Anzoátegui state, Venezuela. Ería. 3 (3): 353-365. https://doi.org/10.17811/er.3.2017.353-365

Parra, R., Olivares, B., Cortez, A. y Rodríguez, M.F. (2012). Patterns of rainfall homogeneity in climatic stations of the Anzoátegui state, Venezuela. RevistaMulticiencias. 12 (Extraordinario): 11-17. https://n9.cl/xbslq

Parra, R., Olivares, B., Cortez, A. y Rodríguez, M.F. 2013. Application of statistics procedures for the quality control of the monthly rainfall series in the Venezuelan Oriental Plains. Rev. Fac. Agron. (LUZ). 30 (3): 367-391.

Parra, R., Olivares, B., Cortez, A., Lobo, D., Rodríguez, M.F. y Rey, J.C. 2018. Characteristics of the meteorological drought (1980-2014) in two agricultural localities in the Venezuelan Andes Revista de Investigación. 42(95):38-55. https://n9.cl/7o7n1

Patil, N. B. 2003. Studies on intercropping of little millet with pigeonpea on Alfisols of Dharwad.M.sc. (Agri.) Thesis.Unvi. Agric. Sci., Dharwad, Karnataka, India

Pramila, R., B. and D. R. Reddy. 2010. Performance of pigeonpea in sole and inter cropping system in vertisols of Krishna-Godavari zone in Andhra Pradesh. *Ind. J. Agric. Res.*44 (3): 225–228.

Rao, J. V. D. K. and P. J. Dart. 1987. Nodulation, Nitrogen Fixation and Nitrogen Uptake in Pigeonpea (Cajanus cajan (L.) Millsp) of Different Maturity Groups .*Plant and Soil.* **99** (2-3):255-266.

Rao, M. R. and R.W. Willey. 1980. Preliminary studies on intercropping combinations based on pigeonpea or sorghum. *Expl. Agric.***16**:29-40

Rathod, P. S., S. I. Halikatti, S. M. Hiremath and S. T. Kajjidoni. 2004a. Influence of different intercrops and row proportions on yield and yield parameters of pigeonpeain Vertisolsof Dharwad. *Karnataka J. Agric. Sci.*17: 652-657.

Rodríguez, M.F., Cortez, A., Olivares, B., Rey, J.C, Parra, R. y Lobo, D (2013). Análisis espacio temporal de la precipitación del estado Anzoátegui y sus alrededores. Agronomía Tropical 63 (1-2): 57-65. https://n9.cl/14iow

Singh, R. A. and A. K. Singh. 1994. Comparative performance of different intercropping systems with pigeonpea under rainfed conditions of Vindhyan region. *Ind. J. Agron.***39**:613-615.

Viloria, J.A.; Olivares, B.O.; García, P.; Paredes-Trejo, F.; Rosales, A. (2023). Mapping Projected Variations of Temperature and Precipitation Due to Climate Change in Venezuela. Hydrology 10, 96. https://doi.org/10.3390/hydrology10040096

Willey**,** R. W. and M. R. Rao.1980.Evaluation of Yield Stability in Intercropping :Studies on Sorghum/Pigeonpea*. J. Expl. Agric.* 16(2)https://doi.org/10.1017/S0014479700010796**.** Published online: 01 October 2008, pp. 105-116Print publication: April 1980

Willey, R. W.1979. Intercropping–its importance and research needs I. Competition and yield advantage. *Field Crops Abst*. **32**:1–10 and 73-85.

Yadav R. L. and K. Prasad. 1997. Efficient farming systems. *Ind. farming.***47**: 30-35.

Yenebala, L., 2017. Study on pigeonpea + niger intercropping system. M.sc. (Agri.) Thesis.V.N.M.K.V., Parbhani, Maharashtra, India.

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Formatted: Spanish (Spain, International Sort)

Zingaretti, M.L., Olivares, B., (2019). Application of multivariate methods for the characterization of periods of meteorological drought in Venezuela. Revista Luna Azul. 48, 172:192. http://dx.doi.org/10.17151/luaz.2019.48.10

Zingaretti, M.L., Olivares, B., Demey Zambrano, J.A. y Demey, J.R. 2017. Application of the STATIS-ACT method to the rain regime in the Venezuelan Oriental Region. UNED Research Journal 9(1): 97-106. https://investiga.uned.ac.cr/revistas/index.php/cuadernos/article/view/1684/1904

Formatted: Portuguese (Brazil)

Zingaretti, ML; Olivares, B. (2018). Analysis of the meteorological drought in four agricultural locations of Venezuela by the combination of multivariate methods. UNED Research Journal. 10 (1):181-192. http://dx.doi.org/10.22458/urj.v10i1.2026

Aiyer A.K.Y.N. 1949. Mixed cropping in India. *Ind. J. Agric. Sci.* **19**:39-443

Anjeneyulo, V.R., S.P. Singh and M. Paul. 1982. Effect of competition free period and techniques and patterns of pearl millet planting on growth and yield of mungbean intercropping system. Indian J. Agron. 27(23): 219-226.

Channabasavanna, A. S., M. S. Kitturmath and H. Rajakumar. 2015. Standardization of sowing date and genotypes of pigeonpea [*Cajanus cajan*(L.) Millsp.] under erratic rainfall conditions in northern dry zone of Karnataka. *Karnataka J. Agric. Sci.* 28(4):604-605.

De Wit, C.T. 1960. On competition. Versl. Landbouwk, Onderzoek 66(8): 1-82.

Dhandayuthapani, U. N., and R. L. Kuzhanthaive. 2015. Analysis of light transmission ratio and yield advantages of pigeonpea in relation to intercrop and different plant population. *Afr. J. Agric. Res.* 10(8):731-736.

Donald, C. M. 1963.Competition among crop and pasture plants. *Advances in Agronomy*.**10**: 435-473.

Gare, B. N., S. M.More, M. G. Jadhav and A. V. Burli. 2004.Effect of pigeonpea and sorghum intercrop on yield of soybean under rainfed condition in Sub- Montane Zone of Maharashtra. *Journa lof Maharashtra Agric. Univ.* **29**(2):170-172.

Hari, R., G. Singh, H.S. Sekhon and Veena Khanna. 2011. Effect of sowing time on the performance of pigeonpea genotypes. *J. Food Leg.* 24(3): 207-210.

Hegde, D. M. 1992. Cropping systems research highlights. Bulletin PDCSR, Modipuram, Meerut, India.

Hiebsch, C.K. and R.E. McCollum.1987.Area time equivalent ratio: A method of evaluating the productivity of intercrops. *Agron. J.* **79**:15-22.

Islam, S., Nanda, M. K. and A. K. Mukherjee. 2008. Effect of date of sowing and spacing on growth and yield of *rabi* pigeonpea [*Cajanus cajan* (L.) Millsp.]. *J. Crop and Weed*. 4(1): 7-9.

Karwasra, R. S. and Kumar. 2007. Response of pigeonpea (Cajanus cajan L.) to NPK in Haryana. *Haryana J.Agron.***23** (1/2): 117

Lal, R. 1994. Water management in various crop production systems related to tillage. *Soil and Tillage Res.* **30**: 169-185.

McGillchrist, I.A. 1965. Analysis of competition experiments. Biometrics 21: 975-985.

Mendhe, S.N., W.S. Pawar and S.R. Ghadekar 2007. Sustainable agriculture. Farming Systems and Sustainable Agriculture: 95.

Panse, V.G. and P.V. Sukhatme. 1967. Statistical methods for agricultural workers. ICAR, New Delhi. pp. 381.

Patil, N. B. 2003. Studies on intercropping of little millet with pigeonpea on Alfisols of Dharwad.M.sc. (Agri.) Thesis.Unvi. Agric. Sci., Dharwad, Karnataka, India

Pramila, R., B. and D. R. Reddy. 2010. Performance of pigeonpea in sole and inter cropping system in vertisols of Krishna-Godavari zone in Andhra Pradesh. *Ind. J. Agric. Res.*44 (3): 225-228.

Rao, J. V. D. K. and P. J. Dart. 1987. Nodulation, Nitrogen Fixation and Nitrogen Uptake in Pigeonpea (Cajanus cajan (L.) Millsp) of Different Maturity Groups . *Plant and Soil.* **99** (2-3):255-266.

Rao, M. R. and R.W. Willey. 1980. Preliminary studies on intercropping combinations based on pigeonpea or sorghum. *Expl. Agric.***16**:29-40

Rathod, P. S., S. I. Halikatti, S. M. Hiremath and S. T. Kajjidoni. 2004a. Influence of different intercrops and row proportions on yield and yield parameters of pigeonpea in Vertisols of Dharwad. *Karnataka J. Agric. Sci.*17: 652-657.

Singh, R. A. and A. K. Singh. 1994. Comparative performance of different intercropping systems with pigeonpea under rainfed conditions of Vindhyan region. *Ind. J. Agron.***39**:613-615.

Willey, R. W. and M. R. Rao.1980.Evaluation of Yield Stability in Intercropping :Studies on Sorghum/Pigeonpea. *J. Expl. Agric.* 16(2)https://doi.org/10.1017/S0014479700010796. Published online: 01 October 2008, pp. 105-116Print publication: April 1980

Willey, R. W.1979. Intercropping its importance and research needs I. Competition and yield advantage. *Field Crops Abst*. **32**:1- 10 and 73-85.

Yadav R. L. and K. Prasad. 1997. Efficient farming systems. *Ind. farming*.**47**: 30-35.

Yenebala, L., 2017. Study on pigeonpea + niger intercropping system. M.sc. (Agri.) Thesis.V.N.M.K.V., Parbhani, Maharashtra, India.

Table 1: PEY, LER, ATER, Aggressivity, RCC, CI and CR as influenced by dates of sowing and different cropping systems during 2016-17 and 2017-18.

Treatments	Yield advantage in intercropping													
	PEY (Kg ha^{1})	LER		ATER		Aggri.		RCC		CI		CR		NMR (Rs.ha^{-1})
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	
A) Dates of sowing														
D_1	1661	1.17	1.19	1.02	1.05	0.46	0.49	1.41	2.28	0.35	0.31	1.39	1.46	43,275
D_2	1508	1.15	1.15	1.00	1.00	0.46	0.50	1.51	1.87	0.36	0.32	1.57	1.51	35,750
D_3	1181	1.19	1.14	1.05	1.00	0.51	0.51	1.24	1.44	0.39	0.36	1.85	1.80	18,174
D_4	876	1.12	1.33	0.99	1.13	0.55	0.37	1.15	1.15	0.46	0.40	2.03	1.66	1,817
B) Cropping systems														
I_1- PP+SOY	1958	1.26	1.31	1.08	1.12	0.43	0.33	2.40	2.52	0.10	0.10	3.01	2.59	54,449
I_2- PP+PM	1616	1.28	1.39	1.15	1.25	1.04	0.45	1.17	2.09	0.30	0.21	1.39	1.58	46,647
I_3- PP + NIG	1624	1.10	1.11	0.84	0.81	-0.50	0.08	0.74	1.12	0.16	0.09	1.45	1.26	42,307
I_4- SOLE PP	1882	1.00	1.00	1.00	1.00	--	--	--	--	--	--	--	--	46,706
I_5- SOLE SOY	831	1.00	1.00	1.00	1.00	--	--	--	--	--	--	--	--	-6,807
I_6- SOLE PM	587	1.00	1.00	1.00	1.00	--	--	--	--	--	--	--	--	-7,001
I_7- SOLE NIG	648	1.00	1.00	1.00	1.00	--	--	--	--	--	--	--	--	-3,024