Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2020; 9(1): 1010-1017
Received: 19-11-2019
Accepted: 22-12-2019

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Validation of different fertilizer levels in maize + pole bean based intercropping system in southern transition zone of Karnataka

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Abstract
A field experiment was conducted during *Kharif* season-2017 and 2018 at Agriculture and Horticultural Research Station, Bavikere. The experiment was laid out in Randomized Complete Block Design with seven treatments and three replication. Maize is grown in paired row of 75/45 cm × 30 cm while pole bean crop was made to grow besides single row of maize in paired row system with 120 cm × 30 cm. Thereby, the whole system had 55,000 and 27,777 population respectively for maize and pole bean. In this system, application 100 per cent RDF of maize (100:50:25 N, P and K kg ha^{-1}) supplied to both the crops (T_1) and application 100 per cent RDF of pole bean (63:100:75 N, P and K kg ha^{-1}) supplied to both the crops (T_2) were tested against, five different combinations of fertilizer levels (150, 125, 100, 75, 50% of RDF of both the crops). Among different fertilizer levels tested, application of 150 per cent RDF of maize and pole bean supplied to both the component crops (244.50:225:150 N, P and K kg ha^{-1}) recorded higher growth attributes like plant height (268.10 cm at harvest), number of leaves (8.93 at harvest), leaf area (89.02 dm^2 plant^{-1} at harvest), stem girth (9.65 cm at harvest) and total dry matter (313.21 g plant^{-1} at harvest,) and yield attributes like cob length (20.58 cm), cob girth (8.22 cm), grain weight cob^{-1} (146.39 g), number of grains row^{-1} (34.47), number of grain rows cob^{-1} (19.37), number of grain cob^{-1} (639.64) and 100 grain weight (31.09 g) and grain (75.21 q ha^{-1}), stover (91.88 q ha^{-1}), cumulative pole bean yield (56.81 ha^{-1}), maize equivalent yield (149.77 q ha^{-1}). Further, it was statistically on par with application of 125 and 100 per cent RDF of maize and pole bean supplied to both the component crops.

Keywords: Maize and pole bean paired row intercropping system, Growth and Yield parameters and Maize equivalent yield

Introduction
Maize is the second most important cereal crop in the World in terms of acreage and is called the 'Queen of Cereals' because of its highest genetic yield potential among the cereals. By origin, crop is native to South Mexico regarded as the most versatile emerging crop having wider adaptability under varied agro-climatic conditions. It is being used as source of food, fodder and also as raw material for starch industries. Global maize production touched 1040 million tonnes during 2016- 17 wherein, US has been the leading producer followed by China, accounting for about 38 and 23 per cent of production, respectively (Anon., 2018) [3] and Indian contribution is around two per cent. In India, it is cultivated in an area of 10.20 m ha with production of 26.00 m t and productivity of 2.60 t ha^{-1}.The maize area in Karnataka has almost doubled during the past one decade and currently it is the largest among all the states in India and also leading producer and exporter with a contribution of about 19 per cent (4 mt) from 15 per cent of maize area (1.33 m ha) with productivity of 2.90 t ha^{-1} (Anon., 2018) [3]. Maize being a C_4 crop produces higher dry matter, having ability to suppress weeds and high adaptability to both rainfed and irrigated situations have favoured expansion of maize area in the state. Maize crop in Southern Transition Zone is being grown as monocrop in an area of 2, 80,540 ha. Continuous growing of maize over the years has resulted in declining of soil fertility and health due to its exhaustive nature. In addition to this, climatic variability, market fluctuation and increase in pest and disease incidence are the major threats for maize cultivation in the zone. One of the ways for sustainable maize production in the zone is through crop diversification with time and space intensification.
Crop diversification refer to a shift from the regional dominance of mono crop to regional production of variety of crops to meet ever increasing demands of cereals, pulses, vegetables, fruits, oil seeds, fibers, fodders, grasses *etc.* Crop diversification brings high spatial and temporal biodiversity in farm thereby increases resilience against climate change, control pests

and diseases, maintains yield and stabilizes nutrients supply with better soil health and ultimately economic stability to the farmers. Crop diversification is imminent to produce additional food from less expense of land through more efficient use of natural resources with minimal impact on the environment in order to meet the increasing population request (Amos *et al.*, 2005) [2]. Mashingaidze (2004) [10] reported that maize based intercropping system effectively utilizes land for obtaining improved yield and hence achieves greater biological and economic stability in the system.

Maize and pole bean as component crop in an intercropping system which improves the soil condition by reducing the amount of nutrient taken from the soil and balances the nutrient for the next season crops. Similarly, Onduru *et al.* (2007) [13] also indicated that intercropping of maize with beans reduced nutrient decline compared with sole cropping of either of the two crops. The difference in growth duration and morphology made it suitable for an alternative system for small scale farmers to improve their income and food production per unit area of land. More productivity of maize/legumes intercropping has been reported by Kamanga *et al.* (2010) [8]. In Ethiopia, shade tolerance and early matured types of common beans are intercropped with sorghum, maize and coffee in southern part of the country but, maize/bean intercropping was dominant (Walelign, 2004) [18]. When common bean intercropped with maize, increased nodulation and nodule longevity was reported by Hungria *et al.* (2010) [7].

Studies conducted earlier identified maize + pole bean as an efficient and viable intercropping system (Afroza, 2016). In her investigation, maize crop was grown under paired row at 75/45 × 30 cm spacing and pole bean crop was sown in every alternate row of maize at plant to plant spacing of 30 cm. Hence, regular spacing of 120 cm × 30 cm for pole bean crop was maintained thereby in this intercropping system, 100 per cent population of both the component crops was maintained under additive series. Roy and Barun (1983) [15] suggested that supplying the recommended dose of fertilizer to both the component crops could increase the yield of an intercropping system. They further stated that the fertilizer needs of component crop in a cereal- legume intercropping systems are likely to be very different from the requirement of respective sole crop, which seems logical as two crops grown in association may or may not exploit the growth resources fully. In order to exploit high yield potentials of both the component crops, nutrient requirement of maize + pole bean intercropping system needs to be standardized as nutrient requirement of both the crops under their respective sole crop is much higher because of their exhaustive nature. Keeping these things in view the present, experiment on “Validation of different fertilizer levels in maize + pole bean based intercropping system in Southern Transition Zone of Karnataka” was undertaken.

Material and Methods

A field experiment was conducted during *Kharif* season of-2017 and 2018 at Agriculture and Horticultural Research station, Bavikere, which is situated in the Southern Transition Zone (Zone-7) of Karnataka. The experimental site is situated at 75º 42' N latitude and 75º 51' E longitude with an altitude of 695 m above mean sea level (MSL). The soil was sandy loam in texture, slightly acidic pH (6.04) and normal in electrical conductivity (0.27 dS m^{-1}), low organic carbon 4.8 g kg^{-1} and medium in available nitrogen (337 kg ha^{-1}), phosphorus (35.37 kg ha^{-1}) and potassium status (255.13 kg ha^{-1}).

Field experiment was laid out in the Randomized Complete Block Design with seven treatments and replication three. Treatments consisted of seven different doses of fertilizer for maize and pole bean (150, 125, 100, 75, 50% of recommended dose of fertilizer N, P and K) in maize + pole bean intercropping system. The pure crops of the respective intercrops were raised separately for computation of LER and ATER. The field was laid out as per plan of layout and the plots were marked. Furrows were opened at 60 cm apart and one seeds per spot was dibbled at 30 cm within a row as per the treatment. In paired row configuration at spacing of 75/45 × 30 cm maize seeds were dibbled in the pairs of furrows opened at the spacing of 45 cm and the spacing given between pairs was 75 cm. The seeds were dibbled in the rows at the spacing of 30 cm under both the methods. The pole bean seeds were placed at about 5-8 cm away to the dibbled maize seed in the same furrow so that pole bean was sown at regular spacing of 120 cm between rows and 30 cm between plants. Fertilizers were applied to both main and intercrop as per the treatment details (RDF for maize-100:50:25 and pole bean-63:100:75 kg N, P_2O_5 and K_2O ha^{-1}). Growth and yield observations of the crops were recorded at 30, 60, 90 days after sowing and at harvest and subjected to statistical analysis.

Treatment details

- T_1: 100% RDF of Maize supplied to both the crops (100:50:25 N, P and K kg ha^{-1})
- T_2: 100% RDF of Pole bean supplied to both the crops (63:100:75 N, P and K kg ha^{-1})
- T_3: 50% RDF of Maize and Pole bean supplied to both the crops (81.5:75:50 N, P and K kg ha^{-1})
- T_4: 75% RDF of Maize and Pole bean supplied to both the crops (122.25:112.5:75 N, P and K kg ha^{-1})
- T_5: 100% RDF of Maize and Pole bean supplied to both the crops (163:150:100 N, P and K kg ha^{-1})
- T_6: 125% RDF of Maize and Pole bean supplied to both the crops (203.75:187.5:125 N, P and K kg ha^{-1})
- T_7: 150% RDF of Maize and Pole bean supplied to both the crops (244.50:225:150 N, P and K kg ha^{-1})

The varieties used were, CP818 a private hybrid of maize, NZ an exotic hybrid of pole bean. All the experimental data on growth parameters and yield were statistically analyzed and critical difference was worked out as described by Gomez and Gomez (1984).

The total yield obtained in the intercropping system from the component crops was converted as maize equivalent yield considering the price and was calculated by using the formula,

$$\text{MEY} = \text{Maize yield (kg ha}^{-1}) + \frac{\text{Intercrop yield (kg ha}^{-1}) \times \text{price (₹. kg}^{-1})}{\text{Maize price (₹ kg}^{-1})}$$

Results and Discussion

Growth parameters of maize

Pooled analysis of the data on (Table 5) total dry matter accumulation indicated that, application of 150 per cent RDF of maize and pole bean supplied to both the component crops (T_7; 9.64,106.75, 256.89 and 313.21g $plant^{-1}$ at 30, 60, 90 DAS and at harvest, respectively) being at par with 125 (T_6; 9.42, 104.33, 251.06 and 306.11 g $plant^{-1}$ at 30, 60, 90 DAS and at harvest, respectively) and 100 per cent RDF of maize and pole bean supplied to both the component crops (T_5; 8.95, 99.11, 238.52 and 290.82 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) but, caused significant improvement in total dry matter accumulation over 50 (T_3) and 75 (T_4) per cent RDF of maize and pole bean supplied to both the crops and100 per cent RDF of pole bean supplied to both the crops (T_2) and 100 per cent RDF of maize crop supplied to both the crops (T_1). Further, total dry matter accumulation plant^{-1} during 2017 and 2018 has also showed similar results as that of pooled data.

The pooled data in Table 1 to 4 indicated that, application of 150 per cent RDF of maize and pole bean supplied to both the component crops (T_7) noticed significantly higher plant height (37.57, 189.54, 262.15 and 268.10 cm at 30, 60, 90 DAS and at harvest, respectively), number of functional leaves (8.23, 18.40, 16.87 and 8.93 at 30, 60, 90 DAS and at harvest, respectively), leaf area (27.45, 86.61, 91.41 and 89.02 dm^2 plant^{-1}, at 30, 60, 90 DAS and at harvest, respectively), stem girth (7.34, 8.09, 8.72 and 9.65 cm at 30, 60, 90 DAS and at harvest, respectively) and it remained stastistically on par with 125 (T_6) and 100 (T_5) per cent RDF of maize and pole bean supplied to both the component crops. Application of 50 (T_3) and 75 (T_4) per cent RDF of maize and pole bean supplied to both the crops, 100 per cent RDF of pole bean supplied to both the component crops (T_2) and 100 per cent RDF of maize crop supplied to both the component crops (T_1) registered significantly lower plant height, number of leaves, leaf area and stem girth over the above treatments. Year wise data on the above parameters during 2017 and 2018 reflected similar trend to that as observed in pooled data.

The pre requisite for getting higher yield in any crop is total dry matter production and it's partitioning into various plant parts coupled with maximum translocation of photosynthates to the sink. Total dry matter accumulation is the sum of dry matter accumulation in different plant parts which depends not only timely availability of moisture, nutrient, sun light *etc.*, but, also plants integrity to use these resources on demand scale.

Economic yield is part of the total biological yield of the crop and hence the crop dry matter is an important determinant of the economic yield (Donald, 1962). Dry weight is one of the most important growth indicators which have been applied as a measure of total photosynthesis; at each plant level usually the response of dry weight is sigmoid in nature. It is also inferred from the data (Table 4.5) that at 30 DAS, the leaves and stem shared equal proportion of dry matter, at 60 DAS the stem is sharing almost 50 per cent dry matter while, another 50 per cent was shared by leaves and young cob. With advance in age at 90 DAS, out of total dry matter accumulation, the share of the cobs was more (almost 45.00%) than stem (35.00%) and leaves (20.00%). Further, at harvest, cobs shared greater proportion (50.00%) of dry matter.

Among different fertilizer levels, application of 100 per cent RDF of maize and pole bean supplied to both the crops (T_5) has realized 15.29 and 22.39 g plant^{-1} lesser dry matter accumulation at harvest over 125 (T_6) and 150 (T_7) per cent RDF of maize and pole bean supplied to both the crops, respectively. On contrary, the said treatment has registered 69.32 and 24.55 g plant^{-1} higher dry matter accumulation over 50 (T_3) and 75 (T_4) per cent RDF of maize and pole bean supplied to both the crops. In maize + pole bean intercropping system lower dry matter accumulation was recorded with application 100 per cent RDF of maize supplied to both the component crops (T_1) and 100 per cent RDF of pole bean supplied to both the component crops (T_2). The total dry matter production and its distribution into various vegetative and reproductive parts indicated good source to sink relationship. Significant increase in total dry matter accumulation plant^{-1} was related to better partitioning of dry matter in stem, leaves and cob in maize plant. Dry matter partitioning at harvest, indicated more contribution towards reproductive part of growth. It might be due to the significant role of NPK in dry matter production. However, light, radiation, humidity, soil moisture, availability of nutrients dictate the dry matter production at large. Further, the reduced dry matter accumulation in intercropping situation was due to imbalance in supply of fertilizer levels and due to partial competition exerted by the component crops for the growth resources during various stages of crop growth. These results corroborate the findings of Singh *et al*. (2003) [17].

Yield and yield attributes of maize

The pooled data (Table 8) indicate that, application of 150 per cent RDF of maize and pole bean supplied to both the component crops recorded higher grain yield (75.21 q ha^{-1}) and straw yield (91.88 q ha^{-1}) being at par with application of 125 (73.51 and 89.18 q ha^{-1}, respectively) and 100 (69.84 and 84.55 q ha^{-1}, respectively) per cent RDF of maize and pole bean supplied to both the component crops and caused significant improvement in maize yield over 50 and 75 per cent RDF of maize and pole bean supplied to both the crops, 100 per cent RDF of pole bean supplied to both the crops and100 per cent RDF of maize supplied to both the crops. During 2017 and 2018 also grain and straw yield recorded in response to different treatments were in line with the pooled data.

The pooled data on yield attributing character of maize in Table 6 and 7 indicate that, significantly higher yield attributing character like cob length (20.58 cm), cob girth (8.22 cm), grain weight cob^{-1} (146.39 g), number of grain row^{-1} (33.46), number of grain rows cob^{-1} (19.37), number of grain cob^{-1} (34.47) and 100 grain weight cob^{-1} (31.09 g) recorded in the treatment received 150 per cent RDF of maize and pole bean supplied to both the crops (T_7). Further, it was statistically on par with application of 125 (T_6) and 100 per cent RDF of maize and pole bean supplied to both the component crops (T_5) as these treatments recorded higher cob length (19.78 and 18.64 cm), cob girth (7.86 and 7.53 cm), grain weight cob^{-1} (143.07 and 136.93 g), number of grain row^{-1} (33.71 and 31.58), number of grain rows cob^{-1} (18.44 and 17.52), number of grains cob^{-1} (606.04 and 567.03) and 100 grain weight cob^{-1} (30.02 and 28.38 g) resulted in significant improvement of maize yield over treatment received 50 (T_3) and 75 per cent RDF of maize and pole bean supplied to both the crops (T_4), 100 per cent RDF of pole bean supplied to both the crops (T_2) and100 per cent RDF of maize supplied to both the crops (T_1).

Maize yield varied significantly due to different fertilizer levels during both the years of study. Maize is grown in paired row while pole bean crop was made to grow besides single row of maize in paired row system. Thereby the whole system has 55,000 and 27,777 population respectively for maize and pole bean. In this system, treatment (T_1) application 100 per cent RDF of maize supplied to both the crops and (T_2) application 100 per cent RDF of pole bean supplied to both the crops respectively. In the system of natural competition, mutual need of the crops paves way for benefit to both the crops. As seen from the data, treatment T_1

and T_2 yielded 57.15 and 44.50 q ha^{-1}, respectively latter treatment yielded 22.13 per cent reduction compared to former treatment. On the other hand, plots received 100 per cent RDF of maize and pole bean supplied to both the crops (T_5) yielded 69.84 q ha^{-1}. As compared to T_5 treatment, both T_1 and T_2 plot yielded 18.17 and 36.28 per cent lesser maize yield. It is mainly due to requirement level of each crop fertilizer is higher. Restriction of respective dose fertilizer to both the crops, naturally shares the resource depending on the soil type, holding capacity, exchangeable pattern *etc.*, there by limits the yield level. The growth pattern from initial stage of crop at harvest (Table 1 to 5) in T_1 and T_2 (plant height 203.72 cm and 158.61 cm, number of leaves 6.78 and 5.28, leaf area 67.64 and 52.66 dm^2 $plant^{-1}$, stem girth 8.54 cm and 8.18 cm and total dry weight 237.99 g $plant^{-1}$ and 185.29 g $plant^{-1}$ at harvest, respectively) and followed by yield component harvest (Table 6 to 7) like cob length (15.20 and 11.40 cm), cob girth (6.14 and 4.64 cm), grain weight cob^{-1} (114.73 and 88.11 g), number of grain row^{-1} (24.93 and 19.30), number of grain rows cob^{-1} (14.34 and 11.07), number of grains cob^{-1} (370.39 and 226.97) and 100 grain weight cob^{-1} (23.02 and 18.26 g) were found statistically lower that of T_5, indicating not only insufficiency of the nutrient supplied but also sharing of fertilizer to the co-component crop.

Further, application of 50 per cent RDF to the respective crop (T_3) limited the yield levels to 53.19 q ha^{-1} slightly lesser than T_1 but higher to that of T_2. However, maize crop in T_3 treatment improved both growth and yield components than T_2 and found on par with that of T_1. It is also true that the yield levels achieved in T_3 treatment did not match the yields obtained in T_5 treatment, indicating the insufficient fertilizer level. By enhancing the fertilizer levels to 75 per cent RDF of maize and pole bean supplied to both the crops (T_4), yield level boosted to 63.94 q ha^{-1} which was on par with T_5 with yield difference of 5.90 q ha^{-1}. Data support improvement of growth and yield component for 75 per cent RDF of maize and pole bean supplied to both the component crops as compared to 50 per cent RDF applied to both the component crops.

The increased maize yield under intercrop was due to nitrogen contribution from pulses as legume effect and also due to microclimate of intercrops favoured the optimum growth and development of maize. Maize is shallow rooted crop which absorbs the nutrient from upper layer of the soil. While, pole bean crop being a deep rooted absorbs the nutrient from deeper layer of soil. Grand growth stage of both the crops did not coincide in utilizing the resources. Increase in yield might be due to better plant performance with optimum levels of fertilizer which was responsible for increased cell division, multiplication and better photosynthetic activity which helped in increase in dry matter production and which also enhanced better root development and resulted in profuse shoot and root growth there by activating absorption of these nutrients from soil in turn ultimately resulted in yield of maize. Singh *et al.* (2003) [17] also reported positive influence with higher levels of fertilizers for yield in base crop. Further, substantial role of well fertilized legume component with respect to transfer of nutrients towards the maize crop also was a reality. Similar findings were reported by Shivay *et al.* (1999) [16]. The similar relationship obtained yet again for major nutrient uptake and yield. Higher values of yield attributing characters by application of higher nutrient levels were also earlier reported by Singh *et al.* (2003) [17]; Bakht *et al.* (2006) [4]; Kunjir *et al.* (2007) [9] and Muniswamy *et al.* (2007) [11]. The response of maize to fertilization levels showed that the grain yield of maize increased with increase in nutrient level. Significant increase in stover yield of maize with application of 150, 125 and 100 per cent RDF of maize and pole bean supplied to both the component crops could be attributed directly to increased dry matter accumulation and indirectly to greater nutrient uptake under this treatment. It may be due to increased availability of nutrients which helped the plant to attain its maximum yield potential. Significantly higher biological yield with aforesaid fertilizer level could be ascribed to its positive influence on both vegetative and reproductive growth of crops which led to increase in grain and straw yield, thereby higher biomass production ha^{-1}. Optimum levels of fertilizer to maize might have enhanced meristematic activities in maize by stimulating cell division and elongation of cells which reflected in the increased plant height and LAI, which in turn provided greater leaf surface for better inception, absorption and utilization of radiant energy which ultimately increased grain yield and straw yield with concomitant improvement in yield attributes.

Vegetable pole bean yield and yield parameters as influenced by different fertilizer levels in maize + pole bean intercropping system

Pooled data on pole bean yield in Table 4 indicated that, application of 150, 125 and 100 per cent RDF of maize and pole bean supplied to both the component crops witnessed higher pole bean yield (56.81, 54.16 and 52.51 q ha^{-1}, respectively) over treatment received 50 (T_3) and 75 per cent RDF of maize and pole bean supplied to both the crops (T_4), 100 per cent RDF of pole bean supplied to both the crops (T_2) and 100 per cent RDF of maize supplied to both the crops (T_1).

In maize + pole bean intercropping system, when recommended dose of fertilizer of pole bean were supplied to maize and pole bean crops (T_2) the pole bean yield was only 36.42 q ha^{-1} which was significantly superior to the treatment T_1. Hence, due to higher quantity of fertilizer applied in this treatment compared to T_1 and there was a significant difference between the two treatments. In spite of reduced fertilizer levels to pole bean in treatment T_1, produced 25.37 q ha^{-1} of green pod yield as pole bean is a component crop due to uniform application of maize RDF supplied to component crop. When elevated levels of fertilizer were given to both the component crops from the lowest level of 50 to 150 per cent RDF of maize and pole bean, yield also enhanced. Yield obtained at 150 per cent RDF (T_7; 56.81 q ha^{-1}) recorded significantly higher compared to 75 per cent (44.12 q ha^{-1}) and 50 per cent (33.15 q ha^{-1}) RDF of maize and pole bean indicating sufficiency of nutrients requirement at 150 per cent and insufficient nutrients at 75 and 50 per cent RDF. However, the higher pole bean yield obtained at 150 per cent RDF of maize and pole bean fertilizer level (T_7) was statistically at par with 125 per cent (T_6; 54.16 q ha^{-1}) and 100 per cent (T_5; 52.51) RDF of maize and pole bean supplied to both the crops. Further, application of 150 per cent RDF of maize and pole bean supplied to both the crops (T_7) has registered 4.66 per cent and 7.56 per cent higher yield over 125 per cent and 100 per cent RDF to both the component crops.

In line with the discussions made for maize yield, here also application of 100 per cent RDF of pole bean supplied to maize and pole bean crops yielded 36.42 q ha^{-1} as against 100 per cent RDF of maize supplied to maize and pole bean crops yielded 25.37 q ha^{-1}. In both the situation there is a partial and mutual cooperation between crops for usage. Where plots received 100 per cent RDF of maize and pole bean supplied to both the component crops (T_5; 52.51 q ha^{-1}), an increase of 30.64 and 51.68 per cent higher pole bean yield was recorded over T_2 and T_1 respectively. Further, by applying 50 or 75 per cent RDF to both the crops there was an improvement in bean yields but, statistically did not reach the level of significance to that of T_5.

Perusal of the above said data indicated that application of 25 and 50 per cent enhanced rate to that of RDF was very much prudent in supplying higher amount of major nutrients and resulted in higher bean yield. Enhanced pole bean yield was mainly attributed to higher fresh weight of pods $plant^{-1}$ at 25 per cent enhanced RDF (T_6; 202.96 g) and 50 per cent enhanced RDF (T_7; 218.05 g). On other hand, lower pole bean yield and yield attributes like fresh weight of pods $plant^{-1}$ at 50 per cent RDF (T_3; 153.57 g) and 75 per cent RDF of maize and pole bean supplied to both the crops (T_4; 182.57 g) were due to inadequate of supply of nutrients to both the component crops. The result envisages the need for application of fertilizer to both the crop to fulfil their nutrient requirement to express their yield potentiality. However, the pole bean crop which received100 per cent RDF of maize supplied to both the crops in the treatment (T_1) yet resulted in getting 144.85 g of fresh weight of pods $plant^{-1}$ by utilizing native soil nutrient besides absorbing nutrients applied to main crop in the maize + pole beam intercropping system.

It is thus clear in the present study that pole bean as an intercrop with maize did not compete for natural resources as well as for other production inputs. Thus, with the suitable spatial arrangement and proper fertilizer management it is possible to minimize inter/intra specific competition. Further, maize crop was not affected by intercropping, while pole bean pod yield was reduced by 50 per cent in intercropping system. Reduction in pole bean yield under intercropping system was attributed to decrease in number of pods per unit area. According to the experiment conducted by Niringiye *et al*. (2005) [12] on same maize + climbing bean intercropping system, the reduction in the intercropped bean yield was associated with the reduced fertilizer level which resulted reduction in the yield per plant, number of pods per plant and provided favourable condition of weather for maize.

Maize equivalent yield (MEY) as influenced by different fertilizer levels in maize + pole bean intercropping system

To express yield advantage, the yields of individual crops are converted into equivalent yield of any one crop based on their economic value. The data is presented in Table 4. The maize equivalent yield as influenced by different fertilizer levels revealed that treatment varied statistically for pooled as well as year wise data.

It was inferred from the results that higher maize equivalent yield was noticed in plots received 150 per cent RDF of maize and pole bean supplied to both the component crops (T_7; 149.77 q ha^{-1}) which is significantly superior to treatment applied with 50 per cent RDF (T_3; 96.06 q ha^{-1}) and 75 per cent RDF (T_4; 120.14 q ha^{-1}) of maize and pole bean supplied to both the crops, 100 per cent RDF of pole bean supplied to both the crops (T_2; 90.85 q ha^{-1}) and 100 per cent RDF of maize supplied to both the crops (T_1; 89.41 q ha^{-1}). However, the treatment received 150, 125 and 100 per cent RDF of maize and pole bean supplied to both the component crops were statistically at par (149.77, 145.58 and 138.33 q ha^{-1} of MEY, respectively). In maize + pole bean intercropping system 100 per cent RDF of maize supplied to both the crops (T_1) and 100 per cent RDF of pole bean supplied to both the crops (T_2) have registered lesser MEY of 89.41 and 90.85 q ha^{-1}, respectively (Table 10). But, pole bean equivalent yield found non-significant.

Though, there was no statistical significance among the treatments 150, 125 and 100 per cent RDF of maize and pole bean supplied to both the component crops. But, 150 per cent RDF of maize and pole bean supplied to maize and pole bean recorded 2.79 and 7.63 per cent higher maize equivalent yield over 125 and 100 per cent RDF of maize and pole bean supplied to both the crops, respectively. Such an increase in maize equivalent yield could be attributed to significantly higher maize grain yield 75.21 q ha^{-1} (Table 10) and pole bean yield 56.81 q ha^{-1} (Table 10) in this treatment by efficient utilization of applied nutrients to both the crops.

In maize + pole bean intercropping system, when both the crops received their respective 100 per cent RDF of maize and pole bean (T_5) recorded 138.33 q ha^{-1} maize equivalent yield which was significantly superior to application of 50 per cent RDF of maize and pole bean (T_3; 96.06 q ha^{-1}), 75 per cent RDF of maize and pole bean (T_4; 120.14 q ha^{-1}), 100 per cent RDF of maize supplied to both the crops(T_1; 89.41 q ha^{-1}) and 100 per cent RDF of pole bean supplied to both the crops (T_2; 90.85 q ha^{-1}). Reduction in maize equivalent yield by 35.36 per cent and 34.32 per cent in the treatment supplied with maize and pole bean 100 per cent RDF to both the crops respectively, indicated shortage of required nutrients to the component crops as compared to both the component crops supplied with 100 per cent RDF of maize and pole bean supplied to both the component crops.

This may also be due to efficient utilization of resources resulting in better productivity. Higher grain yields of component crop owing to optimum nutrient availability (100 per cent RDF to both the component crops) coupled with higher price of both the crops contributed to higher maize equivalent yield. Similar results were reported by Pandita *et al*. (2000) [14] and Hugar and Palled (2008) [6]. In addition to this Significant increase in maize equivalent yield was because of increased levels of fertilizers to main and inter crop which appears to be the result of higher productivity of both maize and intercrops.

Table 1: Plant height (cm) of maize at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	26.56	29.90	28.26	139.7	148.3	144.02	193.2	205.1	199.20	197.6	209.7	203.72
T_2: 100% RDF of pole bean supplied to both the crops (63:100:75)	20.46	23.50	22.01	107.6	116.6	112.13	148.9	161.2	155.09	152.2	164.9	158.61
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	25.27	27.81	26.56	130.2	137.8	134.04	180.1	190.6	185.39	184.1	195.0	189.60
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	29.90	33.97	31.93	154.1	168.1	161.13	213.1	232.5	222.86	217.9	237.8	227.92
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	32.11	37.61	34.89	165.4	186.4	175.99	228.8	257.9	243.41	234.0	263.8	248.94
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	34.05	39.34	36.72	175.4	195.0	185.24	242.6	269.7	256.21	248.1	275.8	262.02
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	34.78	40.31	37.57	179.2	199.8	189.54	247.9	276.3	262.15	253.5	282.6	268.10
S.Em±	0.97	1.15	1.06	5.12	5.70	5.41	7.07	7.88	7.47	7.24	8.06	7.65
CD (P=0.05)	2.99	3.54	3.27	15.76	17.56	16.66	21.80	24.28	23.04	22.30	24.84	23.57

Table 2: Number of functional leaves plant^{-1}of maize at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	6.07	6.44	6.25	13.56	14.39	13.98	12.44	13.20	12.82	6.29	7.26	6.78
T_2: 100% RDF of pole bean supplied to both the crops (63:100:75)	4.67	5.06	4.87	10.45	11.32	10.88	9.58	10.38	9.98	4.84	5.71	5.28
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	5.65	5.99	5.82	12.64	13.38	13.01	11.59	12.27	11.93	5.86	6.75	6.31
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	6.69	7.30	7.00	14.96	16.32	15.64	13.72	14.97	14.34	6.93	8.23	7.58
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	7.18	8.10	7.64	16.06	18.10	17.08	14.73	16.60	15.66	7.45	9.13	8.29
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	7.62	8.47	8.04	17.03	18.93	17.98	15.62	17.36	16.49	7.90	9.55	8.72
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	7.78	8.67	8.23	17.40	19.39	18.40	15.96	17.79	16.87	8.07	9.78	8.93
S.Em±	0.21	0.22	0.21	0.46	0.50	0.48	0.43	0.45	0.44	0.22	0.25	0.23
CD (P=0.05)	0.64	0.68	0.66	1.43	1.53	1.48	1.31	1.40	1.36	0.66	0.77	0.72

Table 3: Leaf area (dm^2 plant^{-1}) of maize at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	20.24	21.48	20.86	63.85	67.77	65.81	67.39	71.52	69.45	65.63	69.65	67.64
T_2: 100% RDF of pole bean supplied to both the crops (63:100:75)	15.59	16.89	16.24	49.19	53.28	51.24	51.92	56.23	54.07	50.56	54.77	52.66
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	18.86	19.97	19.41	59.50	63.00	61.25	62.79	66.49	64.64	61.16	64.75	62.96
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	22.32	24.36	23.34	70.42	76.84	73.63	74.32	81.09	77.71	72.38	78.98	75.68
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	23.97	27.01	25.49	75.62	85.22	80.42	79.80	89.94	84.87	77.72	87.59	82.66
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	25.41	28.25	26.83	80.17	89.12	84.64	84.61	94.05	89.33	82.41	91.60	87.00
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	25.96	28.94	27.45	81.91	91.30	86.61	86.45	96.36	91.41	84.19	93.85	89.02
S.Em±	0.69	0.74	0.72	2.19	2.33	2.26	2.31	2.46	2.38	2.25	2.40	2.32
CD (P=0.05)	2.14	2.28	2.21	6.74	7.18	6.96	7.11	7.58	7.35	6.93	7.38	7.15

Table 4: Stem girth (cm) of maize at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different fertilizer levels in maize based intercropping system

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	6.31	6.56	6.44	6.96	7.23	7.09	7.60	7.90	7.75	8.38	8.71	8.54
T_2: 100% RDF of pole bean supplied to both the crops (63:100:75)	6.11	6.21	6.16	6.74	6.85	6.79	7.36	7.48	7.42	8.11	8.24	8.18
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	6.23	6.40	6.32	6.87	7.06	6.96	7.50	7.71	7.61	8.27	8.50	8.38
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	6.44	6.76	6.60	7.10	7.45	7.28	7.75	8.14	7.95	8.55	8.97	8.76
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	6.60	7.18	6.89	7.27	7.92	7.59	8.04	8.64	8.34	8.76	9.53	9.14
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	6.71	7.26	6.98	7.39	8.00	7.69	8.17	8.74	8.46	8.90	9.64	9.27
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	7.04	7.64	7.34	7.76	8.42	8.09	8.50	8.94	8.72	9.34	9.96	9.65
S.Em±	0.18	0.22	0.20	0.19	0.24	0.22	0.20	0.26	0.23	0.23	0.30	0.26
CD (P=0.05)	0.54	0.67	0.61	0.59	0.74	0.67	0.62	0.81	0.71	0.72	0.91	0.81

Table 5: Total dry matter accumulation (g plant-1) of maize at 30, 60, 90days after sowing (DAS) and at harvest as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	7.10	7.54	7.32	78.70	83.52	81.11	189.39	201.00	195.19	230.91	245.07	237.99
T_2: 100% RDF of pole bean supplied to both the crops (63:100:75)	5.47	5.93	5.70	60.63	65.67	63.15	145.91	158.03	151.97	177.90	192.68	185.29
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	6.62	7.01	6.82	73.33	77.65	75.49	176.48	186.86	181.67	215.17	227.83	221.50
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	7.84	8.55	8.19	86.79	94.70	90.75	208.87	227.91	218.39	254.66	277.87	266.27
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	8.41	9.48	8.95	93.20	105.03	99.11	224.28	252.76	238.52	273.46	308.18	290.82
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	8.92	9.92	9.42	98.81	109.84	104.33	237.80	264.33	251.06	289.93	322.28	306.11
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	9.11	10.16	9.64	100.96	112.53	106.75	242.95	270.82	256.89	296.22	330.20	313.21
S.Em±	0.24	0.26	0.25	2.70	2.87	2.78	6.49	6.91	6.70	7.91	8.43	8.17
CD (P=0.05)	0.75	0.80	0.77	8.31	8.85	8.58	19.99	21.30	20.65	24.37	25.97	25.17

Table 6: Yield attributes of maize as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	Cob length (cm)			Cob girth (cm)			Grain weight cob^{-1} (g)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	14.45	15.95	15.20	5.91	6.37	6.14	109.92	119.54	114.73
T_2: 100% RDF of Pole bean supplied to both the crops (63:100:75)	10.45	12.35	11.40	4.35	4.93	4.64	84.15	92.06	88.11
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	13.53	14.60	14.07	5.57	5.83	5.70	101.57	108.48	105.03
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	16.52	17.81	17.17	6.51	7.11	6.81	119.02	128.87	123.95
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	17.53	19.75	18.64	7.18	7.88	7.53	129.81	144.04	136.93
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	18.58	20.98	19.78	7.47	8.24	7.86	135.51	150.63	143.07
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	18.99	22.16	20.58	7.58	8.85	8.22	138.45	154.33	146.39
S.Em±	0.51	0.54	0.53	0.20	0.22	0.21	3.70	3.94	3.82
CD (P=0.05)	1.56	1.66	1.61	0.62	0.66	0.64	11.39	12.14	11.77

Table 7: Yield attributes of maize as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	Number of grain row^{-1}			Number of grain rows cob^{-1}			Number of grain cob^{-1}			100 grain weight (g)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	23.67	26.18	24.93	13.91	14.76	14.34	353.67	387.10	370.39	22.13	23.91	23.02
T_2: 100% RDF of Pole bean supplied to both the crops (63:100:75)	18.01	20.59	19.30	10.52	11.61	11.07	214.28	239.65	226.97	17.56	18.95	18.26
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	22.99	24.14	23.57	12.96	13.72	13.34	298.61	344.78	321.70	20.99	22.53	21.76
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	27.21	29.69	28.45	15.84	16.74	16.29	419.43	498.87	459.15	24.85	27.11	25.98
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	30.22	32.93	31.58	16.47	18.56	17.52	501.54	632.52	567.03	26.68	30.07	28.38
T_6: 125% RDF of maize and pole bean suppliedto both the crops (203.75:187.5:125)	32.98	34.43	33.71	17.47	19.41	18.44	542.17	669.9	606.04	28.59	31.45	30.02
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	33.65	35.28	34.47	17.84	20.89	19.37	565.98	713.3	639.64	29.95	32.22	31.09
S.Em±	0.85	0.90	0.88	0.48	0.51	0.50	27.26	32.27	29.77	0.77	0.82	0.80
CD (P=0.05)	2.6	2.78	2.69	1.47	1.56	1.52	83.99	99.44	91.72	2.38	2.53	2.46

Table 8: Grain yield, stover yield and harvest index of maize as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	55.45	58.85	57.15	66.60	69.39	67.99	0.43	0.43	0.43
T_2: 100% RDF of Pole bean supplied to both the crops (63:100:75)	42.72	46.27	44.50	55.62	59.15	57.38	0.43	0.42	0.43
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	51.67	54.71	53.19	61.86	64.70	63.28	0.43	0.42	0.43
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	61.15	66.73	63.94	76.40	79.97	78.19	0.42	0.45	0.44
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	65.67	74.01	69.84	82.73	86.37	84.55	0.44	0.45	0.45
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	69.62	77.39	73.51	87.31	91.05	89.18	0.44	0.46	0.45
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	71.13	79.29	75.21	89.86	93.89	91.88	0.44	0.46	0.45
S. Em±	1.90	2.02	1.96	2.43	2.98	2.71	0.02	0.01	0.02
CD (P=0.05)	5.85	6.24	6.04	7.50	9.19	8.34	NS	NS	NS

Table 9: Cumulative fresh weight of pole bean pods plant^{-1}and yield of pole bean as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatments	Cumulative fresh weight of pole bean pods plant^{-1} (g)			Cumulative pole bean yield (q ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	140.60	149.11	144.85	23.12	25.65	25.37
T_2: 100% RDF of Pole bean supplied to both the crops (63:100:75)	168.43	169.48	168.95	33.41	36.65	36.42
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	147.24	159.9	153.57	31.32	33.42	33.15
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	179.63	185.52	182.57	40.12	44.87	44.12
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	188.80	207.64	198.22	48.12	55.57	52.51
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	194.94	210.98	202.96	51.45	57.54	54.16
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	204.83	231.27	218.05	53.52	59.19	56.81
S.Em±	5.62	6.04	5.83	1.61	1.59	1.47
CD (P=0.05)	17.34	18.61	17.97	4.96	4.89	4.54

Table 10: Maize equivalent yield (MEY) and pole bean equivalent yield (PEY) as influenced by different fertilizer levels in maize + pole bean intercropping system

Treatment	MEY (q ha^{-1})			PEY (q ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled
T_1: 100% RDF of maize supplied to both the crops (100:50:25)	87.90	90.91	89.41	62.63	72.73	67.68
T_2: 100% RDF of Pole bean supplied to both the crops (63:100:75)	89.61	92.08	90.85	63.85	73.67	68.76
T_3: 50% RDF of maize and pole bean supplied to both the crops (81.5:75:50)	95.63	96.49	96.06	68.13	77.19	72.66
T_4: 75% RDF of maize and pole bean supplied to both the crops (122.25:112.5:75)	117.46	122.82	120.14	83.69	98.25	90.97
T_5: 100% RDF of maize and pole bean supplied to both the crops (163:150:100)	133.20	143.47	138.33	94.91	114.77	104.84
T_6: 125% RDF of maize and pole bean supplied to both the crops (203.75:187.5:125)	141.84	149.32	145.58	101.06	119.45	110.26
T_7: 150% RDF of maize and pole bean supplied to both the crops (244.25:200:150)	146.25	153.28	149.77	104.20	122.62	113.41
S.Em±	4.01	3.95	3.98	58.81	71.07	64.98
CD (P=0.05)	12.37	12.16	12.27	NS	NS	NS

Conclusion

Application of 150 per cent RDF (244.25:200:150, N, P and K kg ha^{-1}) of maize and pole bean supplied to both the crops recorded improvement in grain yield by 2.26 and 7.14 per cent and maize equivalent yield 3.10 and 8.92 per cent over 125 and 100 per cent of maize and pole bean supplied to both the crops. However, in statistical terms 100, 125 and 150 per cent RDF of maize and pole bean supplied to both the crops were on par with respect to grain yield and maize equivalent yield.

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