



Root and shoot studies of summer cowpea (*Vigna unguiculata*) and baby corn (*Zea mays*) under intercropping system with different levels of fertility and stress-mitigating chemicals

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ABSTRACT

An experiment was conducted during summer seasons of 2019 and 2020 at College of Agriculture (Agriculture University, Kota), Umedganj, Rajasthan, to study the root and shoot of summer cowpea [*Vigna unguiculata* (L.) Walp.] and baby corn (*Zea mays* L.) under intercropping system with different levels of fertility and stress-mitigating chemicals. The experiment was laid out in a split-split plot design with 4 replications having 30 treatment combinations with 5 intercropping systems [sole cowpea; sole baby corn; cowpea + baby corn (2:1); cowpea + baby corn (3:1); and cowpea + baby corn (4:1)] in the main plot and 3 fertility levels, viz. 100; 125; and 150% RDF (Recommended dose of fertilizer) in subplot and 2 stress mitigating chemicals (0.5% CaCl₂ and 1% KNO₃ at flowering and pod development stage of cowpea) in sub-sub plot. Results revealed significant increase in shoot weight, root weight, root-to-shoot ratio, cowpea equivalent yield (CEY) and number and dry weight of nodules in 2:1 row cowpea + baby corn intercropping system over other row ratios. The 2:1 row ratio significantly increased root:shoot ratio of cowpea by 20.9, 15.2, and 7.3% over sole cowpea, 4:1 and 3:1 row ratio, respectively, and resulted in the highest root-to-shoot ratio for baby corn, recording 18.3, 14.5, and 6.8% increase over sole baby corn, 4:1, and 3:1 row ratios of cowpea and baby corn, respectively. Further shoot weight, root weight, root:shoot ratio in cowpea and baby corn, CEY and the number and dry weight of nodules in cowpea exhibited a notable increase in 150% RDF as compared to lower fertility levels (100 and 125% RDF). Applying 150% RDF resulted in a significantly higher root:shoot ratio for both cowpea and baby corn, with increases of 11.3 and 4.5% over 100 and 125% RDF for cowpea, and 11.6 and 5.5% over 100 and 125% RDF for baby corn, respectively. Foliar application of 0.5% CaCl₂ at the flowering and pod-developing stages significantly augmented all the aforementioned parameters for both cowpea and baby corn.

Keywords: Cowpea-baby corn intercropping system, Fertilization, Foliar spray, Root to shoot ratio

Stress conditions during summer season could markedly modify the growth, morphology and root physiology, which would change ion and water uptake (Seleiman *et al.* 2021). Foliar spray of stress-mitigating chemicals, which can alter the physiological/biochemical processes of plants during biotic and abiotic stresses, can be used to manage yield reduction in field crops (Kumar *et al.* 2013). Calcium chloride (CaCl₂) and potassium nitrate (KNO₃) are osmo-protectants and promote photosynthesis, cell division and cell elongation. These chemicals also influence crop growth positively by affecting water uptake, growth of roots, turgor maintenance and activate numerous enzymes under environmental stress condition (Wahid *et al.* 2007). Therefore, cropping techniques that effectively manage

elevated temperatures during the crop growth stage are crucial for achieving optimal crop growth and yield. Cereal-legume intercropping plays a vital role in subsistence food out-turn, mainly in situations of limited water resources (Dahmardeh *et al.* 2009). The combination of a legume crop with non-legume, generates yield advantages over sole cropping (Iqbala *et al.* 2020), because of differential canopy architectures. Baby corn (*Zea mays* L.) has tall canopies, whereas cowpea [*Vigna unguiculata* (L.) Walp.] has short canopies. Furthermore, the vital metabolites and water released on topsoil by legumes as root exudes regale to the water requirement of maize crop during the time of short dry spells.

Low crop yields in a significant part of India might be attributed to diminishing soil nutrients, with nitrogen playing a crucial role in growth and physiological functions. The appropriate management of nitrogen is essential to establish a balanced set of growth indices in the crop canopies, ultimately leading to improvements in yield. Phosphorus,

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another vital macro-nutrient, is integral to various essential plant structural compounds and acts as a catalyst in key biochemical reactions. Its capacity to capture solar energy and convert it into beneficial plant components further emphasizes its importance.

Studying the impact of intercropping, fertility levels, and stress-mitigating chemicals on the root and shoot parameters of cowpea and baby corn is crucial for optimizing agricultural practices. This research helps to uncover synergies or competitions between crops in intercropping, fine-tune nutrient management for growth, particularly with nitrogen and phosphorus, and enhance crop resilience to environmental stressors. The findings provide practical insights for farmers, aiding in sustainable and efficient crop management to improve overall agricultural productivity and food security under the south-eastern zone of Rajasthan.

MATERIALS AND METHODS

A field study was carried out during summer seasons of 2019 and 2020 at College of Agriculture (Agriculture University, Kota), Umedganj, (25°13' N latitude and 75°28' E longitude; elevation of 271 m amsl), Rajasthan. It falls under central plateau and hills zones of India (VIII) and humid south-eastern plain zone (V) of Rajasthan. The weekly meteorological weather observations recorded during the crop period are summarized below. In the year 2019, the mean daily maximum and minimum temperatures experienced fluctuations, ranging between 32.1–47.3°C and 17.1–33.6°C, respectively. For the year 2020, these temperatures varied between 37.0–44.5°C (maximum) and 17.4–24.4°C (minimum). The average daily relative humidity showed fluctuations as well, ranging from 24.4–74.6% in 2019 and 30.4–73.29% in 2020. The mean daily open pan evaporation, measured using the USWB class A pan evaporimeter, ranged from 2.1–5.6 mm/day in 2019 and 2.7–5.0 mm/day in 2020. In terms of precipitation, there was recorded rainfall of 41 mm in 2019 and 33.7 mm in 2020.

The soil in the field experiment exhibited a clay loam texture, comprising 25.10% sand, 40.12% silt, and 34.78% clay. It possessed favourable characteristics, being relatively deep with commendable drainage properties, as indicated by an average bulk density of 1.26 mg/m³. The soil in the experimental area demonstrated moderate levels of organic carbon (0.52%), available nitrogen (313 kg/ha), and phosphorus (23.05 kg/ha). It registered a slightly alkaline pH of 7.6 and showcased a high potassium content at 394 kg/ha.

The experimental trial was laid out in split-split plot design with 4 replications. In the main plots, there were 5 intercropping systems, viz. cowpea sole; baby corn sole; cowpea + baby corn as 2:1; cowpea + baby corn as 3:1; and cowpea + baby corn as 4:1 row ratio. Three levels of fertility, viz. 100, 125, and 150% RDF were applied in sub-plots and 2 stress mitigating chemicals (0.5% CaCl₂ and 1% KNO₃) in sub-sub plots. Stress mitigating chemicals were applied at flowering and pod development stage of cowpea.

Baby corn var. G 5414 and cowpea var. GC 4 were used in the study. To ensure the use of healthy and mature seeds, cowpea and baby corn seeds were simultaneously sown at rates of 30 kg/ha and 25 kg/ha, respectively.

The intercropping system was adopted in replacement series and crops were sown in the first week of April for both the years. The calculated fertilizer doses of three fertility levels 100% (N₂₀ P₄₀), 125% (N₂₅ P₅₀) and 150% RDF (N₃₀ P₆₀) were drilled before sowing in earmarked plots as per treatment through urea and SSP, respectively in sub-plots. At flowering and pod development stages of the cowpea, stress mitigating agents CaCl₂ at the rate of 0.5% and KNO₃ at the rate of 1% were sprayed with a knapsack sprayer in the sub-sub plots.

Shoot weight and root weight: The root and shoot biomass at 50 DAS were quantified for five randomly selected plants within the designated experimental plot. Subsequently, the plants were carefully uprooted, and the roots and shoots were meticulously separated. The separated plant tissues were subjected to a drying process under shade conditions for 48 h. Following the initial drying phase, the samples underwent further desiccation within a hot air oven set at a temperature of 60°C. The desiccation process continued until a consistent and unchanging weight of both root and shoot samples was achieved. This meticulous procedure was employed to ensure precise and reliable measurements of the plant biomass components.

Root to shoot ratio: The root-to-shoot ratio was determined at 50 days after sowing (DAS) by carefully extracting and separating the roots and shoots of individual plants. Each plant's roots were detached at the soil line, and the weights of the roots and shoots were recorded separately after the drying process. The root-to-shoot ratio (R/S ratio) was calculated using the formula:

$$\text{Root to shoot ratio} = \frac{\text{Dry weight of root}}{\text{Dry weight of shoot}}$$

No. of nodules/plant at 40 DAS: The number of nodules was assessed for each of the five selected plants, and the mean number of nodules/plant was calculated at 40 days after sowing.

Nodule dry weight (mg/plant) at 40 DAS: The counted nodules of the five plants were dried and weighted separately and recorded as nodule dry weight/plant. After counting the nodules on each of the five selected plants, the next step involved individually drying and weighing the nodules from each plant. The resulting values were recorded as the nodule dry weight/plant.

RESULTS AND DISCUSSION

Effect of intercropping system

Shoot weight, root weight, and root: shoot ratio of cowpea: The intercropping system had a significant effect on the shoot dry weight, root dry weight, and root:shoot ratio of summer cowpea. The 2:1 row ratio of summer cowpea and baby corn significantly enhanced the shoot weight, root

Table 1 Effect of intercropping systems, N P fertilization and stress mitigating chemicals on root and shoot parameters of summer cowpea and baby corn (mean of 2 seasons)

| Treatment | Shoot weight (g/m row length) at 50 DAS | | Root weight (g/m row length) at 50 DAS | | Root to shoot ratio at 50 DAS | | Number of nodule/plant of cowpea at 40 DAS | Nodules dry weight of cowpea (mg/plant) at 40 DAS |
|-----------------------------------|---|-----------|--|-----------|-------------------------------|-----------|--|---|
| | Cowpea | Baby corn | Cowpea | Baby corn | Cowpea | Baby corn | | |
| <i>Intercropping system</i> | | | | | | | | |
| Sole cowpea | 93.64 | - | 20.93 | - | 0.223 | - | 19.70 | 63.01 |
| Sole baby corn | - | 133.72 | - | 41.64 | - | 0.310 | - | - |
| Cowpea + Baby corn (2:1) | 104.90 | 159.75 | 69.42 | 58.77 | 0.269 | 0.367 | 24.96 | 69.42 |
| Cowpea + Baby corn (3:1) | 99.78 | 150.20 | 67.37 | 51.75 | 0.251 | 0.343 | 23.03 | 67.37 |
| Cowpea + Baby corn (4:1) | 95.33 | 140.32 | 65.09 | 45.22 | 0.234 | 0.321 | 20.89 | 65.09 |
| SEm± | 1.05 | 2.18 | 0.77 | 1.06 | 0.004 | 0.004 | 0.30 | 0.77 |
| CD (P=0.05) | 3.13 | 6.47 | 2.28 | 3.15 | 0.010 | 0.013 | 0.90 | 2.28 |
| <i>Fertility level (NP)</i> | | | | | | | | |
| 100% RDF | 95.35 | 137.02 | 22.09 | 43.72 | 0.231 | 0.317 | 20.97 | 63.66 |
| 125% RDF | 98.45 | 145.41 | 24.26 | 49.02 | 0.245 | 0.335 | 22.21 | 66.30 |
| 150% RDF | 101.44 | 155.57 | 26.19 | 55.30 | 0.257 | 0.354 | 23.25 | 68.70 |
| SEm± | 0.70 | 1.80 | 0.31 | 0.74 | 0.003 | 0.003 | 0.23 | 0.56 |
| CD (P=0.05) | 2.00 | 5.11 | 0.87 | 2.12 | 0.007 | 0.010 | 0.64 | 1.58 |
| <i>Stress mitigating chemical</i> | | | | | | | | |
| CaCl ₂ @0.5% | 100.23 | 150.49 | 25.23 | 51.99 | 0.250 | 0.343 | 22.61 | 67.10 |
| KNO ₃ @1.0% | 96.59 | 141.50 | 23.14 | 46.71 | 0.238 | 0.327 | 21.68 | 65.34 |
| SEm± | 0.82 | 1.19 | 0.36 | 0.57 | 0.002 | 0.003 | 0.12 | 0.39 |
| CD (P=0.05) | 2.31 | 3.37 | 1.03 | 1.61 | 0.007 | 0.008 | 0.35 | 1.10 |

weight, and root/shoot ratio (Table 1) of summer cowpea compared to the 3:1, 4:1 row ratio, and sole cowpea. The increment in these parameters might have been due to the shading effect of baby corn on cowpea, which reduced the adverse effects of higher temperature stress on cowpea by improving the microclimate of plants during summer months. Similar results of higher growth attributes due to intercropping were also reported by Das *et al.* (2017), Ayele (2020), and Mndzebele *et al.* (2020).

Shoot weight, root weight, and root:shoot ratio of baby corn: The different cowpea + baby corn intercropping treatments also affected the shoot weight, root weight, and root/shoot ratio of baby corn significantly (Table 1). The sowing of baby corn in intercropping with cowpea increased the dry matter of shoot and root, as well as root:shoot ratio significantly over sole planting of baby corn. The spatial arrangement of crops in intercropping systems was a critical factor that exerted substantial influence on the utilization efficiency of solar radiation and available space. This arrangement significantly impacted how effectively the crops captured sunlight and occupied the spatial environment, particularly in scenarios involving the concurrent cultivation of two or more species. Furthermore, the favourable environment fostered by the main crop, cowpea, played a pivotal role in the success

of intercropping. The nitrogen-fixing capacity of cowpea enhanced the availability of atmospheric nitrogen in the soil. This augmented nitrogen availability was hypothesized to have been partially assimilated by the baby corn plants. The utilization of nitrogen, in turn, was believed to contribute to the improved growth and development of the baby corn plants, ultimately resulting in improved attributes such as yield and overall plant vitality. Telkar *et al.* (2018) reported higher dry matter of maize in the intercropping system than sole crop at harvest.

Number of nodules and weight of nodules of cowpea: Both number of nodules and nodule dry weight/plant in cowpea showed a significant increase in the intercropping system compared to sole cowpea, being the maximum with 2:1 row ratio (Table 1). Results suggests that interspecific facilitation in intercropping may contribute to the enrichment of exudates, providing a greater carbon source for the growth and reproduction of specific rhizobium in the cowpea rhizosphere. Consequently, this promotes the nodulation of cowpea in the intercropping system. The outcomes of this study align with the findings of Banik and Sharma (2009) in baby corn and legume intercropping systems, Cun *et al.* (2014) in faba bean and garlic intercropping systems, and Liu *et al.* (2017) in faba bean and wheat intercropping systems.

Cowpea equivalent yield (CEY): Results (Fig. 1) reveals

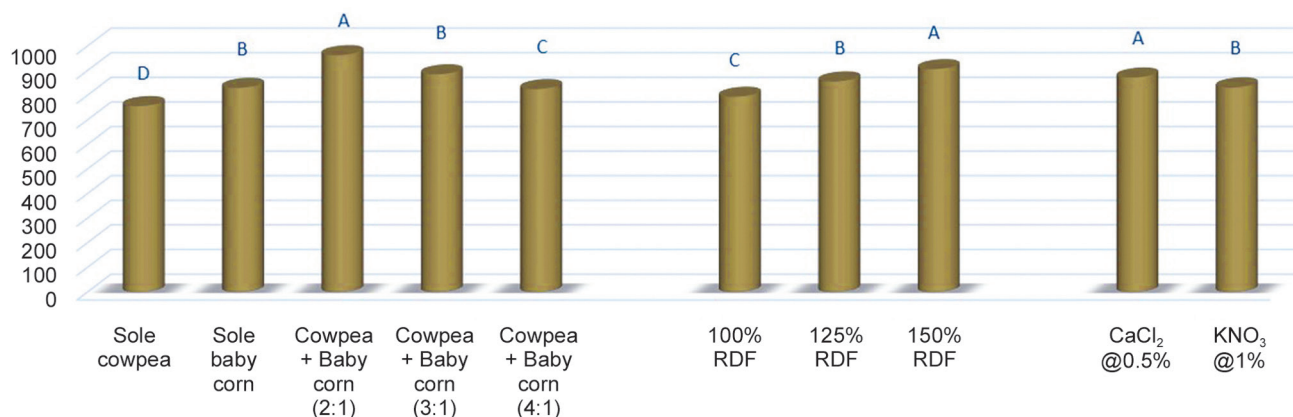


Fig. 1 Effect of different intercropping systems, fertilizer levels and stress mitigating chemicals on cowpea equivalent yield (kg/ha) (mean of 2 seasons).

RDF, Recommended dose of fertilizer.

that intercropping cowpea and baby corn in a 2:1 row ratio led to a significantly increased CEY of 963 kg/ha. This yield surpassed that of sole cowpea by 27.38%, sole baby corn by 16.02%, and the 4:1 and 3:1 row ratio by 16.73% and 8.81%, respectively. These results align with previous research by Devi and Singh (2018), which consistently highlighted the economic and agronomic advantages associated with intercropping strategies.

Effects of fertility levels

Shoot weight, root weight and root:shoot ratio of cowpea: The results of the study demonstrated that the recommended dose of fertilizers at 150% (30 kg N and 60 kg P₂O₅/ha) had a favourable impact on the biomass production of shoot, root, and the root-to-shoot ratio of summer cowpea. All these parameters exhibited a linear increase with the corresponding rise in nitrogen (N) and phosphorus (P) levels. The increments were statistically significant compared to 100 and 125% RDF (Table 1).

The observed improvements in these parameters were likely brought about by an increase in the quantity of substances responsible for growth and naturally occurring phytohormones, particularly in response to a higher nitrogen supply. The potential increase in auxin supply with elevated nitrogen levels contributed to the enhanced dry matter production. These enhancements could be attributed to the early and abundant availability of nitrogen, creating a better nutritional environment in the root zone, thereby facilitating growth and development. Furthermore, the increased supply of phosphorus, recognized as an essential constituent for all living organisms, plays a crucial role in the conservation and transfer of energy in the metabolic activities of cells, including biological energy transformations. In terms of significance, phosphorus is an essential mineral nutrient for pulses, as it enhances root growth and development. This, in turn, makes pulses more efficient in the fixation of biological nitrogen (BNF), as outlined by Prasad (2006).

Shoot weight, root weight and root:shoot ratio of baby corn: The application of 150% recommended dose

of fertilizer (NP) significantly enhanced the shoot weight, root weight, and root-to-shoot ratio of baby corn (Table 1). This improvement could be attributed to the increased levels of nitrogen and phosphorus (NP), which provided a more favourable nutrient supply to the baby corn. The escalating NP levels possibly resulted in a balanced supply, thereby improving various growth parameters such as plant height and dry matter production. Consequently, this balanced nutrient supply contributed to an increase in yield attributes and overall yield of baby corn. The accelerated division and elongation of cells, particularly in response to increased fertility levels, especially nitrogen, played a role in improving photosynthesis and protein synthesis. This, in turn, led to robust plant growth. Furthermore, phosphorus fertilization contributed to the enhancement of various metabolic and physiological processes, which were subsequently utilized for both vegetative and reproductive growth through phosphorylation. These findings align with similar observations reported by Kumar *et al.* (2015) and Balai *et al.* (2017).

Number of nodules and weight of nodules in cowpea: The application of 150% recommended dose of nitrogen and phosphorus at an adequate level resulted in a notable increase in both the number and weight of root nodules of summer cowpea in the current experiment compared to earlier levels (Table 1). The observed augmentation in the number and weight of root nodules in response to the application of nitrogen and phosphorus in this experimentation aligns with the findings of previous studies by Keshwa *et al.* (2009) in cowpea, as well as Daramy *et al.* (2017) and Mndezebele (2020). These consistent results across studies suggest the positive impact of nitrogen and phosphorus application on enhancing the development and weight of root nodules in summer cowpea.

Cowpea equivalent yield: The highest cowpea equivalent yield, amounting to 906 kg/ha, was achieved through the application of 150% RDF (Fig. 1). This marked an increase of 14.1% and 5.8% compared to the utilization of 125% and 100% RDF, respectively. These outcomes align with the conclusions drawn by Ali *et al.* (2012).

Effects of stress mitigating chemicals

Shoot weight, root weight and root:shoot ratio of cowpea: Results shows that the application of 0.5% CaCl₂ significantly elevated all parameters of summer cowpea, including the dry matter of shoot, root, and the root-to-shoot ratio, in comparison to the application of 1.0% potassium nitrate KNO₃ (Table 1). This increase is likely attributed to the favourable impact of foliar application of 0.5% CaCl₂, leading to improved photosynthetic efficiency. Similarly, the beneficial effects of foliar spray of CaCl₂ on cowpea were reported by Choudhary and Yadav (2011), supporting the notion that the application of calcium chloride positively influences various growth parameters in cowpea.

Shoot weight, root weight and root:shoot ratio of baby corn: The application of 0.5% CaCl₂ through spray at the flowering and pod development stages of cowpea led to a significant improvement in the shoot, root, and root-to-shoot ratio of baby corn when compared to the application of 1.0% KNO₃ (Table 1). This enhancement is likely attributed to the improved photosynthetic efficiency resulting from the foliar application of 0.5% CaCl₂. Furthermore, the findings align with a study by Naeem *et al.* (2017), which reported that foliar-applied calcium induces drought stress tolerance in maize. This tolerance was attributed to the manipulation of osmolyte accumulation and antioxidative responses, ultimately promoting the growth of maize. Therefore, the positive effects observed in the present study may be linked to the improved photosynthetic efficiency and potential stress tolerance induced by the application of 0.5% CaCl₂ in the flowering and pod development stages of cowpea, as seen in baby corn.

Number of nodules and weight of nodules of cowpea: Results indicate that the application of 0.5% CaCl₂ significantly increased both the number of nodules and the dry weight of nodules per plant in cowpea compared to the application of 1.0% KNO₃ (Table 1).

These findings are consistent with a study by Choudhary and Yadav (2011), which reported the beneficial effects of foliar spray of CaCl₂ on cowpea. Therefore, the positive impact of 0.5% CaCl₂ on the nodulation characteristics of cowpea, as observed in the current study, aligns with previous research highlighting the advantageous outcomes of calcium chloride foliar applications in enhancing nodulation in cowpea plants.

Cowpea equivalent yield: The evaluation of two stress-mitigating substances (Fig. 1) demonstrates that the foliar administration of a 0.5% CaCl₂ solution markedly boosted the cowpea equivalent yield to 872 kg/ha. This improvement was substantial in comparison to employing a 1.0% KNO₃ solution. Specifically, the cowpea equivalent yield witnessed a 4.81% increase with the application of 0.5% CaCl₂ as opposed to the use of 1.0% KNO₃.

REFERENCES

Ali M, Ali A and Yaseen M. 2012. Growth and yield response of hybrid maize through integrated phosphorus management. *Pakistan Journal of Life and Social Sciences* **10**: 59–66. <https://>

- agris.fao.org/agris-search/search.do?recordID=PK2013000313
- Ayele M. 2020. Evaluation of the effect of maize-legume intercropping on soil moisture improvement in arid area of Bena-Tsemay district, south Omo zone of southern Ethiopia. *International Journal of Research and Innovation Technology* **10**(1): 80–86.
- Balai R C, Meena L R and Sharma S C. 2017. Effect of different level of nitrogen and phosphorus on cowpea (*Vigna unguiculata*) under rainfed condition of Rajasthan. *Journal of Agriculture and Ecology* **3**: 19–24.
- Banik P and Sharma R C. 2009. Yield and resource utilization efficiency in baby corn-legume intercropping system in the eastern plateau of India. *Journal of Sustainable Agriculture* **33**: 379–95.
- Choudhary G L and Yadav L R. 2011. Effect of fertility levels and foliar nutrition on cowpea productivity. *Journal of Food Legume* **24**(1): 67–68.
- Cun Z X, Chen J B, Xiu X H and Tang D S. 2014. The influence of intercrop mode and planting density on faba bean nodulation and plant growth. *Journal of Yunnan Agricultural University* **29**: 514–20.
- Dahmardeh M, Ghanbari A, Syasar B and Ramrodi M. 2009. Intercropping maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) as a whole-crop forage. *Journal of Food Agriculture and Environment* **7**(2): 505–09.
- Daramy M A, Addo J S and Dumbuya G. 2017. Effect of nitrogen and phosphorus fertilizer application on growth and yield performance of cowpea in Ghana. *Journal of Experimental Biology and Agricultural Sciences* **5**(1): 38–44.
- Das S, Devi K N, Athokpam H S, Lhungdim J and Longjam M. 2017. Chickpea (*Cicer arietinum* L.) based intercropping system with rapeseed (*Brassica juncea* L.) on growth, yield and competition indices. *Environment and Ecology* **35**(1B): 427–30.
- Devi M T and Singh V K. 2018. Productivity of field pea (*Pisum sativum*) and baby corn (*Zea mays*) intercropping systems as affected by planting pattern and weed management. *Indian Journal Agronomy* **63**: 157–62.
- Iqbala S, Akhtar J, Naz T, Riaz U, Hussain S, Mazhar Z and Iqbal M M. 2020. Root morphological adjustments of crops to improve nutrient use efficiency in limited environments. *Communications in Soil Science and Plant Analysis* **51**: 2452–465.
- Keshwa G L, Yadav L R and Verma K. 2009. Response of cowpea to phosphorus and biofertilizers. (In) *International Conference on Grain Legumes: Quality Improvement, Value Addition and Trade*, 14–16 February, Indian Institute of Pulses Research, Kanpur, Uttar Pradesh.
- Kumar B, Singh Y, Ram H and Sarlach R S. 2013. Enhancing seed yield and quality of Egyptian clover (*Trifolium alexandrinum* L.) with foliar application of bio-regulators. *Field Crops Research* **146**: 25–30. <http://dx.doi.org/10.1016/j.fcr.2013.03.004>
- Kumar R, Bohara J S, Singh A K and Kumawat N. 2015. Productivity, profitability and nutrient use efficiency by corn (*Zea mays*) as influenced of varying fertility. *Indian Journal of Agronomy* **60**(2): 285–90.
- Liu Y C, Qin X M, Xiao J X, Tang L, Wei C Z, Wei J J and Zheng Y. 2017. Intercropping influences component and content change of flavonoids in root exudates and nodulation in faba bean. *Journal of Plant Interaction* **12**(1): 187–92.
- Mndzebele B, Ncube B, Fessehazian M, Mobhavdhi T, Amoo S, Pboy C, Venter S and Modi A. 2020. Effect of cowpea-amaranthus intercropping and fertilizer application on soil

- phosphate activity, available soil phosphorus and crop growth response. *Agronomy* **10**: 79–95.
- Naeem M, Naeem M S, Ahmad R and Ahmad R. 2017. Foliar applied calcium induces drought stress tolerance in maize by manipulating osmolyte accumulation and antioxidative responses. *Pakistan Journal of Botany* **49**(2): 427–34.
- Prasad R. 2006. *Field Crops Production*, 3rd edn, pp. 343. Directorate of Information and Publication of Agriculture, Indian Council of Agricultural Research, Krishi Anusandhan Bhavan, Pusa, New Delhi.
- Seleiman M F, Al-Suhaibani N, Ali N, Akmal N, Alotaibi M, Refay Y, Dindaroglu T, Abdul-Wajid H H and Battaglia M L. 2021. Drought stress impacts on plants and different approaches to alleviate its adverse effects. *Plants* **10**: 259. <https://doi.org/10.3390/plants10020259>
- Telkar S G, Singh A K and Kant K. 2018. Determination of effective spatial arrangement for intercropping of maize + soybean using dry matter yield and competition interaction. *Journal of Pharmacognosy and Phytochemistry* **7**(4): 2239–245.
- Wahid A, Gelani S, Ashraf M and Foolad M R. 2007. Heat tolerance in plants: An overview. *Environmental and Experimental Botany* **61**: 199–223. <http://dx.doi.org/10.1016/j.envexpbot.2007.05.011>