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RESEARCH

Interspecific Facilitation of Nutrient Uptake and Productivity Performance of Finger Millet-Green Gram Intercropping System under Varying Moisture Availability

A.G.U.N. Senevirathne, D.M.S.B. Dissanayaka*, S.H.N.P. De Silva

Department of Crop Science, Faculty of Agriculture, University of Peradeniya

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Senevirathne, A.G.U.N.
https://orcid.org/0000-0003-2221-5507

ABSTRACT

Finger millet (FM/ Eleusine coracana L. Gaertn.) and green gram (GG/ Vigna radiata L. Wilczek) are suitable crops to be cultivated under moisture-limited conditions. This experiment investigated the interspecific facilitation of nitrogen (N) and phosphorus (P) uptake and productivity performance of FM-GG intercropping system under moisture-stressed conditions. In a pot experiment, two crop species were cultivated as mono-cropping and intercropping under two moisture levels (well-watered and moisture-stressed). Soil moisture in well-watered condition was maintained at 80% of field capacity, whereas moisture-stress was imposed with 40%. Plant dry weight, panicle/ grain yield, uptake of N and P, and use efficiency of those nutrients in biomass production were measured. Moisture-stress significantly ($P<0.05$) decreased the panicle/grain dry weight of FM and GG. Though intercropping had no yield advantage for FM or GG either in well-watered or moisture-stressed conditions, intercropped FM under drought stress and well-watered conditions had respectively 42% and 53% greater grain N accumulation than those of its monocultures. FM grown with GG acquired more ($P<0.05$) N than those cultivated in mono-cropping system indicating the interspecific facilitation of N uptake by FM in intercropping. Grain N accumulation of FM was also enhanced in intercropping system. There were no P benefits from the intercropping. The study indicates that interspecific facilitation of nutrient uptake in FM-GG intercropping happens only for N, resulting in grain N fortification of FM. Incorporation of legumes, particularly green gram, into FM cultivation in drought-prone areas could be a potential strategy for grain N enrichment of FM.

*Corresponding author- dissanayakauop@yahoo.com

INTRODUCTION

Finger millet (FM/ *Eleusine coracana* L. Gaertn) is a crop commonly cultivated in semi-arid and arid regions of the world, particularly in South Asia and Africa (Thilakarathna and Raizada, 2015). It is widespread in arid regions mainly due to its ability to adapt in moisture-limited conditions. Finger millet is a rich source of fiber, calcium, iron and other minerals. It has the potential to intercrop with different legumes, particularly in drought prone environment. Green gram (GG/ *Vigna radiata* L. Wilczek) is an annual legume belongs to the family Fabaceae and a rich source of protein with higher digestibility. Green gram seed contains around 24% protein and 36% minerals (Nadeem et al., 2004). The crop is widely cultivated in Asia and some parts of Africa and Australia. The cultivation extent of GG in the world is about six million hectares per year (Pataczek et al., 2018). In general, GG is a prime source of human food and animal feed. Apart from that, it plays an important role in improving soil fertility by symbiotic atmospheric N_2 fixation (Naik et al., 2020). Harvest residues of GG can also be used as manure to enhance soil nutrient content. Green gram is well adapted to tropical and subtropical environments and relatively resistant to drought and heat stresses, therefore could be a better candidate for intercropping systems in drought prone environments (Pataczek et al., 2018).

Cereal-legume intercropping is one of the sustainable cultivation practices that improves cropping system productivity through efficient resource utilization such as light, heat, water, and nutrients (Foley et al., 2011). Apart from that, intercropping is an eco-functional practice that has been widely used to provide a balanced diet, minimize crop failures caused by adverse biotic and abiotic effects, maximize the use of limited resources, increase yield stability, and provide additional income compared to sole cropping (Tsubo et al., 2005; Bitew et al., 2019). However, the cropping combination should be compatible with each other in intercropping because the yield of the companion crop could be reduced compared to sole cropping under incompatible crop combinations (Banik et al., 2008). Since FM and GG are shown to have the ability to tolerate dry conditions, they might be a better combination to cultivate in lands where frequent drought events occur.

One of the key advantages of intercropping systems is the interspecific nutrient facilitation between species leading to improved nutrient uptake (Gunes et al., 2007). In cereal-legume intercropping, interspecific nutrient facilitation takes place in different modes. Firstly, legumes symbiotically fix atmospheric N_2 and enrich soil N making part of the fixed N available to companion plants (Maitra et al., 2020). Furthermore, root exudates such as carboxylates and phosphatases released by some legume roots under phosphorus (P)-deficient conditions facilitate the conversion of unavailable P forms into plant available forms (Gunes et al., 2007). In addition, cereal plants secrete phytosiderophores into the rhizosphere under iron (Fe)-limited conditions and facilitate Fe and zinc (Zn) uptake of legume (Dissanayaka et al., 2021). Therefore, interspecific nutrient facilitation in cereal-legume intercropping could happen in both directions; from legume to cereal and vice versa.

Excessive drought brought on by global climate change is a significant obstacle to agricultural production (Dahal et al., 2019). The deficit of soil moisture inhibits plant growth by reducing water absorption. Furthermore, drought stress significantly affects root growth and nutrient diffusion in soil towards the root system, thereby reducing nutrient uptake by plants. Drought conditions can lower N uptake from the soil and reduce its concentration in plant tissues. This reduction in N uptake is mainly due to inhibited root growth and decreased N transport through the soil to the root surface. In cases of severe drought, roots may shrink and lose contact with the surrounding soil resulting in significant reduction of N uptake (Buljovcic and Engels, 2001). Other than that, plants under water-deficit conditions show a reduction in net photosynthesis and transpiration (Samarah et al., 2004). Drought stress negatively impacts developmental growth phases and reduces the period of light interception partly contributing to yield reduction of crops (Barnabas et al., 2008). There are many other morphological, physiological, and biochemical changes in plants in response to moisture stress (Mukami et al., 2019).

The global food demand is increasing continuously with rapidly growing human population and is expected to double by 2050. Land and water shortages are the major challenges to enhancing agricultural productivity (Yin et al., 2020). Therefore, the use of sustainable cropping systems which can withstand drought stress is of significant importance to increase productivity under global environmental change. It has been demonstrated that intercropping is practiced with limited resources and can enhance yields with greater stability in a variety of crop combinations (Maitra et al., 2020). This is particularly important to achieve food security in low-input cropping systems in arid and semi-arid regions. Therefore, the present study was conducted to investigate the interspecific facilitation of nutrient (N and P) uptake and productivity performance of FM-GG intercropping system under well-watered and moisture-stress conditions with the focus of improving crop production in water-limited landscapes.

METHODOLOGY

Experimental location

A pot experiment was conducted in a greenhouse at the Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka. The experiment was conducted from August to December 2022. The soil type used for the experiment was Red Yellow Podzolic. The mean minimum and maximum temperatures during the experimental period were 31.5°C and 19.2°C respectively.

Growth medium preparation and seed establishment

The growth medium was prepared by mixing soil with sand in a 2:1 ratio to produce a N-limited medium. Characteristics of the growth medium is presented in Table 1. Pots of 30 cm in height and 30 cm in diameter were prepared using 300-gauge polythene. Each pot was filled with 15 kg of potting medium. Finger millet variety-Rawana and GG variety-MI6 were used for the experiment. Certified seeds were obtained from the Field Crops Research and Development Institute, Mahailuppallama, Sri Lanka. A nursery was established to get healthy and uniform seedlings. Two weeks after nursery period, plants were transplanted into pots. In the mono-cropping system, two plants from the same species were cultivated (2FM or 2GG) whereas one plant from each species (1FM and 1GG) was planted in the mixed-cropping system. Fertilizer was added to each pot as a basal dressing according to the recommendation for FM by the Department of Agriculture, Sri Lanka. The rate of application was, 65 kg/ha of Urea, 55 kg/ha of Triple Super Phosphate, and 75 kg/ha of Muriate of Potash.

Experimental design and treatments

The experiment was conducted as a two-factor factorial in a Completely Randomized Design (CRD) with three replicates per treatment. Factor 1 was the moisture level and factor 2 was the cropping system/crop combination. Factor 1 had two levels; 80% of field capacity (well-watered condition) and 40% of field capacity (moisture-stress) (Li et al., 2023). There were three crop combinations for factor 2; sole FM, sole GG, and FM-GG intercropping. Altogether, there were six treatment combinations.

Determination of field capacity of growth medium and imposition of drought treatment

A pot was filled with 1kg of air-dried growth medium and weight of the pot was measured. Then, the pot was flooded with water and kept for one day and then allowed to drain excess water for another day. The wet weight of the soil was measured. The amount of water that needs to reach the field capacity of the soil was calculated from the weight difference. The volumetric water content of the same soil was measured using a digital soil moisture meter. At the field capacity, the volumetric water content of the growth medium was 25%.

Table 1: Chemical properties of growth medium used in the experiment

Parameter	Value
pH	5.81 ± 0.23
EC (ds/m)	0.11 ± 0.01
Available phosphorus (mg/kg)	2.67 ± 0.41
Exchangeable K (mg/kg)	72.22 ± 5.55
Total nitrogen (g/kg)	0.25 ± 0.02

Data represent the mean of three replicates ± SE (standard errors). For pH and EC measurements, soil water ratio of 1:2.5 was used.

All pots were adjusted to 80% field capacity (20% volumetric water content) at the beginning. Soil moisture was measured using a digital soil moisture meter in two-day intervals. If the moisture level drops, water was added to reach the 80% field capacity. Drought treatment was imposed with the onset of flowering of GG. At this stage, FM had reached the six-leaf stage. In drought treatment, soil in the pots was allowed to dry out without irrigation until soil moisture dropped to 40% of field capacity. Hereafter, soil moisture was maintained at 40% field capacity for the rest of the growth period. When soil moisture drops below 40% field capacity, the required amount of water was added to the pots.

Harvesting of plants and measurements

Plants were harvested at their physiological maturity. During the harvesting, shoot was cut from the base of the plant and pods of GG and ear heads of FM were separated. In GG, pods were harvested selectively based on the maturity of pods. Green gram pod weight per plant and FM panicle weight per plant in different cropping systems were recorded. The root system was carefully uprooted from the bag with soil lot, kept on a sieve horizontally, washed carefully to remove all adhering soil from the root system without damaging the roots. All roots were recovered and used to measure root dry weight. All samples including roots, shoots, and pods or ear heads were oven-dried at 70°C until a constant weight to determine dry weights. After oven drying, samples were ground to analyze tissue N and P concentrations. Nitrogen and P concentrations were measured using Kjeldahl method (Nelson and Sommers, 1973) and molybdo-vanado-phosphate method (Kitson and Melon, 1944), respectively. The concentration of a particular nutrient of each plant organ was multiplied by the dry weight of the same organ to estimate the nutrient content of the plant organ. Then, the nutrient contents of different plant organs were added together to quantify total plant nutrient uptake by the plant. Nutrient use efficiency in biomass formation was calculated by dividing total plant dry weight (g/plant) from total nutrient acquired (mg/g) by the plant (Jayamanna et al., 2022; Senevirathna et al., 2024).

Statistical analysis

All the data were analyzed using Statistical Analysis System (SAS) software with Analysis of Variance (ANOVA) and mean separation was done with Duncan's Multiple Range Test. For all the analyses, statistical significance was considered as $p<0.05$. Means are presented along with standard error.

RESULTS AND DISCUSSION

Organ-specific dry matter partitioning

Moisture level significantly influenced the dry weight of panicles and whole plant of FM whereas cropping system and interaction effect (moisture level x cropping system) had no impact (Table 2). Root and shoot dry matter formation of FM was not significantly different under two moisture levels as well as under two cropping systems (Table 2). In GG, there was a significant difference ($p<0.05$) in root and shoot dry weight across two moisture levels except shoot dry weight under well-watered intercropping system. On average across two cropping systems, shoot dry weight of GG was reduced by 44% in drought treatment than that in well-watered conditions. The relevant reduction in root dry weight of GG was 36%. There was no significant impact of cropping system on panicle/pod dry weight and total plant dry weight of both crops. Both FM and GG recorded the greatest panicle/pod and total plant dry weight when they were grown under well-watered conditions (Table 2). On average across two cropping systems, panicle dry weight and total plant dry weight of FM cultivated under drought conditions were reduced by 56% and 37% respectively, compared to those under well-watered conditions. Similarly, relevant reductions of GG were 57% and 48% respectively (Table 2). The partitioning of dry matter is the product of the flow of assimilates from leaves (source organs) along the transport route to the reproductive/storage organs (panicles and grains) (Amanullah et al., 2021). It has been previously shown that the dry matter partitioning and accumulation in plants are high under well-watered conditions compared to moisture-stressed conditions leading to a greater yield of crops grown in moisture-sufficient conditions (Zhiipao et al., 2023; Zhang et al., 2024). This phenomenon is evident in the present study where both FM and GG produced significantly greater yield under well-watered conditions than in moisture-stress (Table 2). Furthermore, the present results are in consistent with the findings of Guttieri *et al*. (2001), Plaut *et al*. (2004) and Amanullah *et al*. (2021), who demonstrated that grain weight is reduced under moisture-limited conditions for a range of crops including wheat, pearl millet, sorghum, rapeseed, barley, and fababean. Dry weights of stems, leaves and heads/pods of millet, sorghum, mungbean and pigeon pea at anthesis and at physiological maturity were significantly affected by both irrigation and intercropping (Singh et al., 2003; Amanullah et al., 2021). In the present study, only the moisture treatment impacted the grain yield and the cropping system had no influence on yield of FM and GG (Table 2). Greater panicles/pods dry weight of FM and GG in well-watered plants under all cropping systems could be due to more translocation of assimilates to those organs as indicated by De Costa and Shanmugathasan (2000). Moisture stress can decrease leaf area thus, reduced photosynthesis and transpiration rate leading to lower dry matter production, and limiting the translocation of assimilates to sink organs (Meena et al., 2015; Amanullah et al., 2020). Under water-stressed conditions, plants start accumulation of assimilate in root and stem whereas in well-watered conditions, assimilates divert into the reproductive organs (Daryanto et al., 2017).

The effect of intercropping on dry matter production depends on several factors including the crop combination, planting density, intercropping pattern, and nutrient availability in soil (Skelton and Barrett, 2005; Arya et al., 2007; Maitra et al., 2020). Studies have shown that intercropping can often lead to higher total plant dry matter production compared to monoculture particularly when the crop combinations are compatible and complementary in terms of utilization of below ground resources such as water and nutrients (Li et al., 2001; Ross et al., 2004; Ghosh et al., 2006; Strydhorst et al., 2008; Wahla et al., 2009; Amanullah et al., 2021). However, in the present study, intercropping did not lead to a greater dry matter accumulation or yield advantage either in FM or GG cultivated under two different soil moisture availability. Although the exact reason for the lack of positive biomass gain in the intercropping system is unclear, one possible explanation could be the limited space for root growth in the pots, which may have restricted the uptake of other nutrients, resulting in no biomass gain. Similarly, Li *et al*. (2021) found that an improvement in P uptake in the millet-chickpea intercropping system under P-limited conditions did not lead to a yield increase.

Table 2: Dry weight of different plant organs and total plant of FM and GG cultivated in two cropping systems under varying moisture availability

Crop	Moisture treatment	Cropping System	Dry weight (g/plant)			
			Shoot	**Root**	**Panicles/pods**	**Total plant**
FM	Drought (40% FC)	Mono-cropping	4.05±0.01a	0.57±0.07a	2.02±0.39b	6.64±0.37c
		Intercropping	4.51±0.19a	0.55±0.09a	2.67±0.29b	7.72±0.32bc
	Well-watered (80% FC)	Mono-cropping	5.50±0.69a	0.59±0.05a	5.49±0.60a	11.73±1.43a
		Intercropping	5.22±0.51a	0.58±0.12a	5.35±0.84a	11.15±1.46ab
ANOVA						
Moisture (M)			NS	NS	***	**
Cropping System (C)			NS	NS	NS	NS
M x C			NS	NS	NS	NS
GG	Drought (40% FC)	Mono-cropping	1.48±0.23b	0.13±0.01b	1.11±0.16bc	2.72±0.37c
		Intercropping	2.45±0.07b	0.12±0.03b	0.62±0.08c	3.20±0.05bc
	Well-watered (80% FC)	Mono-cropping	4.15±0.70a	0.20±0.02a	2.20±0.25a	6.55±0.96a
		Inter cropping	2.95±0.56ab	0.19±0.01a	1.84±0.35ab	4.98±0.76ab
ANOVA						
Moisture (M)			**	**	**	**
Cropping System (C)			NS	NS	NS	NS
M x C			*	NS	NS	NS

Values represent the means of three replicates ± SE (standard error). Values in a column not followed by a common letter are significantly different (*p<0.05*). Statistical analyses were conducted separately for two crops. *FM* finger millet, *GG* green gram, *FC* field capacity. ***, **, *: significant at *P<0.001*, *P<0.01*, and *P<0.05*, *NS*: not significant.

Interspecific facilitation of nitrogen uptake in intercropping of FM-GG

Moisture level, cropping system, and their interaction had a significant impact on N uptake of both crops (Fig. 1A & B). Finger millet accumulated more N in intercropping system compared to mono-cropping under both moisture levels (Fig. 1A). For example, intercropped FM had 20% greater N uptake than that in mono-cropping system under moisture-limited condition (40% FC). The respective increase under well-watered condition was 60%. In contrast, GG showed significantly lower (*p>0.05*) N uptake when intercropped with FM. Nitrogen use efficiency (NUE) of FM was influenced by only the cropping system whereas both moisture level and cropping system had significant impacts on NUE of GG (Fig. 1B). In FM, highest NUE could be observed under well-watered mono-cropping system while all other treatments recorded similar NUE (Fig. 1B). The highest NUE was recorded by monocropped FM under well-watered conditions whereas the lowest was shown by monocropped GG under the same moisture regime (Fig. 1A). When N uptake is reduced, both crops enhanced the efficiency of biomass production per unit of N acquired. Finger millet had significantly greater grain N concentration in the intercropping system than sole cropping in both moisture levels (Fig. 2). For example, intercropped FM under drought stress and well-watered conditions had respectively 42% and 53% greater grain N accumulation than those of its monocultures under respective moisture regimes (Fig. 2).

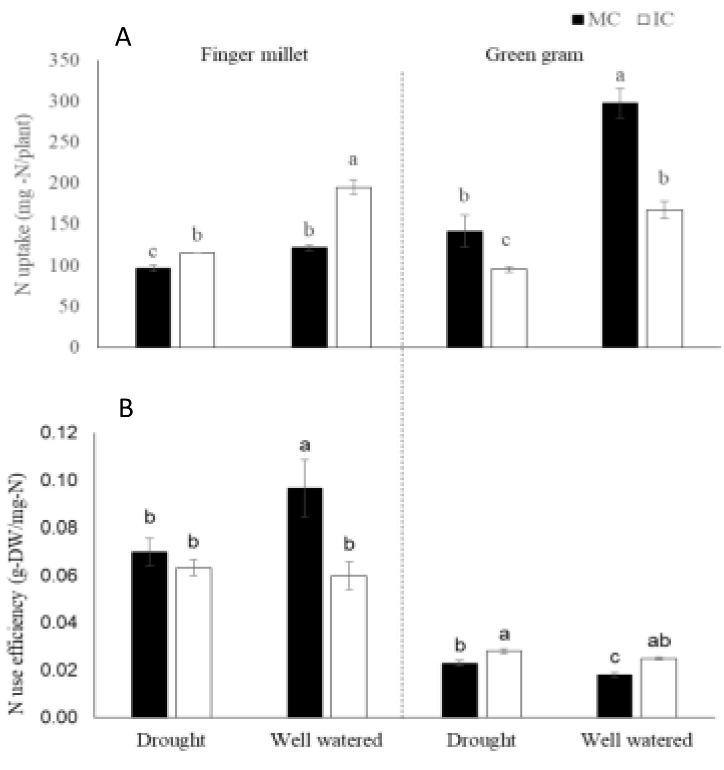

Figure 1: Nitrogen uptake (A) and N use efficiency (B) of FM and GG under different cropping systems and two moisture levels. Means followed by the same letters are not significantly different at *P<0.05*. Error bars represent the standard error (S.E.; n = 3). Statistical analysis were conducted separately for two crops. *MC*-Monocropping, *IC*-Intercropping.

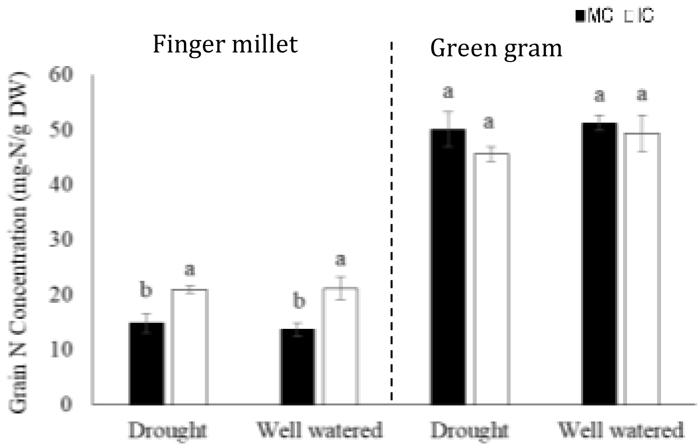

Figure 2: Grain nitrogen concentration of FM and GG under different cropping systems and two moisture levels. Means followed by the same letters are not significantly different at *P<0.05*. Error bars represent the standard error (S.E.; n = 3). Statistical analysis were conducted separately for two crops. *MC*-Monocropping, *IC*-Intercropping.

The intercropping benefits are mainly based on the complementarity in utilization of nutrients, light radiation, and water due to the ecological niche differences between the intercropped species (Han et al., 2022). When cereals and legumes are cultivated together in an intercropping system under N-limited conditions, N nutrition of cereal is improved since the associated legume transfers part of the symbiotically fixed N to the cereal (Meena et al., 2015). Root facilitative interactions in legume and non-legume mixtures can result in belowground facilitation of N uptake of co-existing non-legume species (Pirhofer-Walzl et al., 2012; Frankow-Lindberg and Dahlin, 2013). Results of this study suggest that FM gets N uptake benefits when it is intercropped with GG irrespective of the moisture treatment (Fig. 1A). In cereal-legume intercropping, legume tends to increase N fixation ability through producing more root nodules (Latati et al., 2016). For example, rhizobial symbiosis was significantly increased in both common bean and cowpea intercropped with maize. Such an increase was associated with high N availability in the rhizosphere of common bean and cowpea in intercropping system from which maize could access part of the N (Latati et al., 2016). In addition, decaying root nodules and N-containing root exudates from legume could enhance N availability in legume rhizosphere in which cereal could access to part of it if the root intermingling/rhizosphere overlapping between cereal-legume is strong. In the present study, those facilitative mechanisms could have come into effect in facilitating N uptake of FM when it is intercropped with GG. Moreover, this result is consistent with the work by Bitew *et al.* (2020) for intercropping where N facilitation took place from the direction of haricot bean to FM. However, maize-peanut intercropping did not positively affect farmland N use efficiency, peanut yield, and water use efficiency under drought and N-shortage (Han et al., 2022). These contrasting findings indicate that sharing the benefits of intercropping through complementarity depends on the compatibility of the species combinations that are intercropped. Reduced N uptake under the monocropping system might have resulted in strong competition between root systems of two FM plants. Higher N uptake in intercropped FM than GG could be resulted due to greater root competitive ability of FM than GG because it has been shown that fine roots of cereals facilitate more efficient exploration of the soil in searching nutrients under nutrient-limited conditions (Martin and Snaydon, 1982; Hauggaard-Nielsen et al., 2001). This is further evident by reduced N uptake of GG when it is co-cultivated with FM both under well-watered and water-limited conditions (Fig. 1A). It is a common phenomenon that plants tend to increase the use efficiency of acquired nutrients when the nutrient uptake is reduced (Nitschke et al., 2017; Nieves-Cordones et al., 2020; Jayamanna et al., 2022; Senevirathna et al., 2024). This was also observed in the present study.

Apart from the improved N cycling, cereal-legume intercropping is considered as a natural biofortification option that may improve the nutritional composition of the edible part of the component crops particularly N, P, Fe and Zn (Zuo and Zhang, 2009; Xue et al., 2016; Dissanayaka et al., 2021). The increase in grain N concentration of FM in intercropping system suggests that the FM-GG intercropping could be used as an agronomic intervention for grain N biofortification of FM. This increase in grain N accumulation happened even under drought conditions (Fig. 2). Finger millet is a crop mainly grown in arid and semi-arid areas that depends on less amount of rainfall and soil moisture (Gupta et al., 2017; Maharajan et al., 2021). Hence, the incorporation of legumes, particularly GG, into FM cultivation in drought-prone areas could be a potential strategy for grain N enrichment.

Phosphorus uptake and use efficiency in intercropping

Phosphorus uptake of FM was significantly ($p<0.05$) influenced by moisture level and interaction of moisture x cropping system. Furthermore, cropping system had no impact on P uptake by FM (Fig. 3A). Moisture level was the only factor that determined P uptake of GG in this study. Greater P uptake in well-watered conditions is realized due to the availability of sufficient moisture for plants to acquire nutrients. Both crops recorded significantly greater P uptake under well-watered conditions where P use efficiency (PUE) was reduced (Fig. 3A & 3B). However, in both FM and GG, P uptake was not significantly different across the cropping systems indicating that P facilitation had not happened in FM-GG intercropping as in the case of N. Generally, cereal-legume intercropping promotes P uptake of cereal under P-deficient conditions owing to several P facilitation pathways occurring from the direction of the legume to the cereal (Shimizu et al., 2004). For example, P-mobilizing compounds secreted from some legumes solubilize unavailable P fractions in the rhizosphere and share the P-benefit with cereal (Latati et al., 2014; Dissanayaka et al., 2015; Messaoudi et al., 2020; Tang et al., 2020). Plant species vary in their capacity to mobilize organic P/ fixed P and some P acquisition traits are species-specific. Species that secrete P-mobilizing compounds such as phosphatases or carboxylates thereby convert P into available forms, are considered as P-mobilizing species, whereas species having no such mechanism are known as non-P-mobilizing species (Li et al., 2007; 2014). Positive interactions between two intercropped species can be expected when two species exhibit different P-acquisition strategies (Tang et al., 2020). For example, P uptake of wheat and maize was increased by intercropped faba bean facilitated through rhizosphere acidification as a result of releasing organic acids and protons, which mobilized insoluble inorganic P (Li et al., 2007; 2016). In the present study, such P benefit was not observed when FM was intercropped with GG under two moisture levels (Fig. 3A). This might be due to the fact that growth medium used in the present study was not limited with available P for the growth of both species as P fertilizer was applied to growth medium. Although, initial growth medium had available P concentration of 2.67 mg/kg, application of Triple Super Phosphate at a rate of 55 kg/ha should have increased the available P concentration to a sufficient level for plant growth, thereby eliminating P-mobilizing capacity of GG that normally happens under P-deficient conditions.

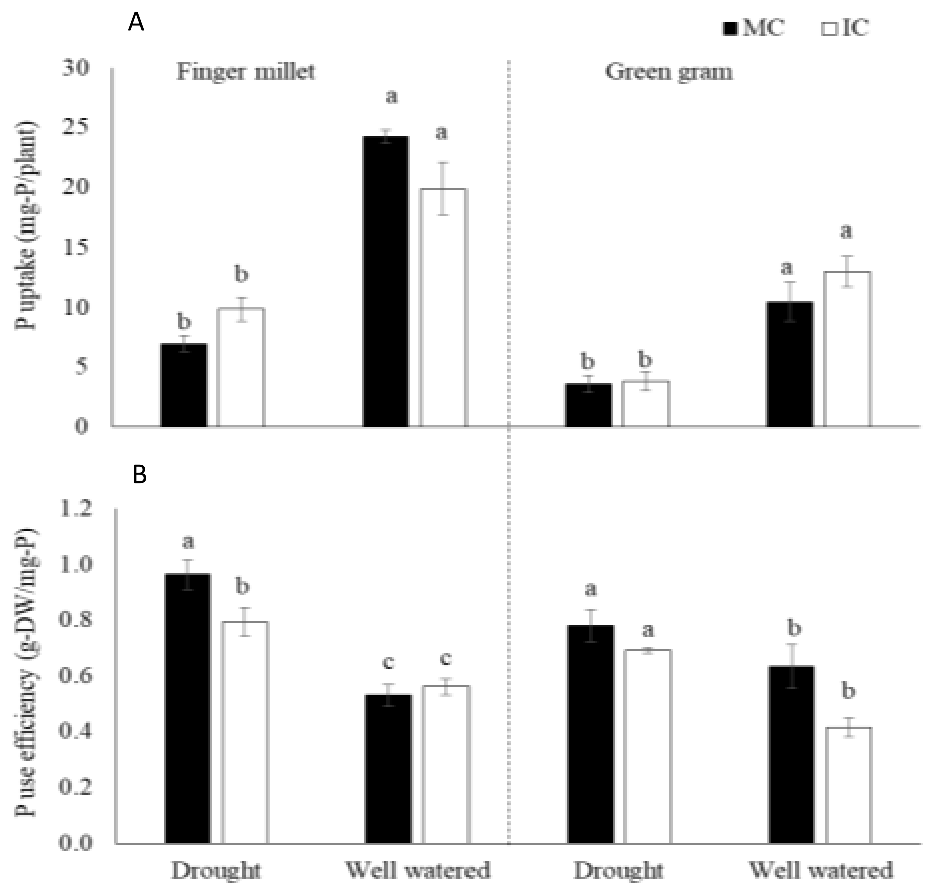

Figure 3: Phosphorus uptake (A) and use efficiency (B) of FM and GG under different cropping systems and two moisture levels. Means followed by the same letters are not significantly different at *P<0.05*. Error bars represent the standard error (S.E.; n = 3). Statistical analyses were conducted separately for two crops. *MC*-Monocropping, *IC*-Intercropping.

CONCLUSION

Though FM-GG intercropping did not appear to increase the overall crop productivity in terms of yield advantage, total plant N uptake and grain N concentration of FM was significantly increased when it is intercropped with GG under drought and well-watered conditions. Furthermore, results demonstrate that interspecific facilitation of N uptake in FM-GG occurs in favor of FM both under drought and well-watered conditions. Drought caused a significant reduction in N and P uptake in FM resulting in lower panicle dry weight. Though intercropping system has no advantage of P accumulation of FM both in drought and well-watered conditions, it can be concluded from the results that FM-GG intercropping system could facilitate N uptake of FM and can be considered as a potential option for agronomic biofortification of grain N of FM, particularly in drought-prone lands where FM is commonly cultivated.

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