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THE EFFECT OF NANO-IRON CHELATED FERTILIZER ON AGRONOMIC ASPECTS OFMILLET-COWPEA INTERCROPPING

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ABSTRACT

This study was conducted to evaluate the effects of spraying of nano-iron chelate on millet-cowpea intercropping with regard to the importance of nano-chelates in improving crop yield and environmental preservation and to achieve sustainable agriculture goals. The experimental design was split based on randomized complete block design with three replications during 2015, at research field of Agriculture and Natural Resources of Bampour, Iran. Spraying of nano-chelated iron at 0, 1, 2 and 3‰ in two stages of branching and flowering comprising main-plots and 5 cropping systems including; millet sole culture, cowpea sole culture, 100% millet+20% cowpea, 100% millet+ 40% cowpea and 100% millet+ 60% cowpea. Results indicated that interaction of nano-iron chelate and cropping systems was significant on all studied traits (except leaf number of both crops and LER). Mean comparison revealed that the greatest millet grain yield was obtained from plant sprayed with nano-iron at concentration of 3‰ and millet sole culture equals to 1021.33 kg ha^{-1} and the lowest millet grain yield was obtained from non-sprayed plant and 100% millet+20% cowpea equals to 442.83 kg ha^{-1}.The results of the experiment confirmed that nano-iron chelated was effective on intercropping of millet and cowpea, so that plant sprayed at concentration of 3‰ had greatest morphological characteristics and yield of the both crops.

Key words: Cereal-legume intercropping, Nano fertilizer, Iron concentration, LER.

INTRODUCTION

In recent years, consideration has been focused on the diversified farming systems for maximizing resources use in comparison with the sole crops (Li *et al.,* 2001). The improved utilization of resources leads to higher total yields of intercropping in contrast with monoculture systems of the same plant grown on the same space. This attributes to differentiation in soil fertility improvement through the addition of N by biological N fixation and exclusion from the legume component and ability of competitive for growth factor between intercrop components in space and time and (Crews and Peoples, 2004). As well as, intercropping is anticipated to increase food security and eliminate risk of a single crop defeat because of pest and disease incidence (Bjorkman *et al.,*2005).

Cowpea (*Vigna unguiculata*) is rich in protein and suitable for human diet as well as for animal feed. Further useful effects of cowpea are the ability of symbiotic N fixation and supplying N for farming systems, reduced pest and disease incidence, hormonal effects by rhizo-excretion and improve soil structure (Ehlers and Hall, 1997). Monoculture of sensitive and small crop species such as cowpea against undesirable situations impose damage of yield and quality due to pests and disease. Pearl millet (*Pennisetum glaucum*) is a main crop grown in the arid areas of Iran. Interest in pearl millet has risen mainly because of important characteristics such as high biomass yield and rapid growth, as well as tolerance to a broad range of pH and soil types (Jain and Bal, 1997).

In Iran due to prevailing conditions of calcareous soils, high pH, undesirable chemical consumption, and in particular the excessive consumption of phosphorus, non-compliance with crop rotation, the consumption of sufficiently contaminated goods, and reduced consumption of food supplements in the past today, the deficiency of these elements in soils and as a result of the nutrition is more evident (Ghaffari Malayeri *et al.,* 2012). Therefore, to provide the required elements of the plant, increasing yield and quality of the crops in these areas, due to low nutrient use efficiency, nutrient leaf spraying is beneficial and effective (Rafique *et al.,* 2015). According to the reports mung bean and millet are sensitive to iron deficiency in the soil, and the deficiency of these element can lead to leafy yellowing and a severe decline in yield (Reed *et al.,* 1988).

A large number of studies have shown the benefit of N-fixing with non N-fixing [For instance, cowpea-scarlet eggplant (*Solanum aethiopicum* L.) (Ofori and Gamedoagbao, 2005), sorghum–soybean (Redfearn *et al.,*1999), barley–lupine, barley–bean and barley–faba (Strydhorst *et al.,*2008), peanut–maize (Inal *et al.,*2007), wheat–pea (Ghaley *et al.,*2005), and wheat–lentil (Gunes *et al.,*2007), leek–celery (Baumann *et al.,*2001). To the best of our knowledge no study exists the leguminosae crops as cowpea intercropped with pearl millet.

Chlorosis induced by iron (Fe) deficiency is common in plants grown in arid regions (Rombolà and Tagliavini, 2006). This chlorosis is distinguished by interveinal yellowing of youngest leaves. Various Fe fertilizers utilized either to soil or leaves to alleviate Fe chlorosis (Tagliavini*et al.,* 2000). Deficiency of Fe usually prevents plant growth through lessen water absorption and nutrient uptake and is a significant limiting factor for crop productivity on calcareous soils. However, crop species in an intercropping system may differ in their reaction to growth following application of Fe fertilizer, because grasses supply Fe to legume crops after reduction of Fe^{3+} to Fe^{2+} at the plasma membrane (Vizzotto *et al.,* 1999).

Previous studies have shown that understanding the effect of different plant nutrition methods in order to optimally use climatic factors, agronomic management and agricultural inputs can be effective in increasing the production with the desired quality of the product and reducing the use of chemical fertilizers (Ghasemi *et al.,* 2013). In this regard, due to the importance of nano-fertilizers in improving crop yield and environmental protection, this study was conducted to investigate the foliar application of iron nano-chelates on the quantitative and qualitative characteristics of millet and cowpea in different cropping patterns for sustainable agricultural purposes. The aims of this research were to assess the influence of Fe fertilizer application on the yield and yield components of cowpea-pearl millet row intercropping compared to respective monoculture.

MATERIALS AND METHODS

Experimental field site description: Field experiments were carried out in 2015 on agricultural experimental farm of Agriculture and Natural Resources Center of Iranshahr (60°24′ N, 27°1′ E, 525 m a.s.l.) in southeast Iran. Some Physiochemical properties of soil was presented in Table 1. Mean annual rainfall and mean annual temperature in experimental site is 115.7 mm and 29.2 °C, respectively. The past crop was forage sorghum (*Sorghum bicolor*), and there was no precedent of Fe fertilizer utilization at the experimental site.

Experimental layout: Seed-bed preparation consisted plowing, harrowing and cultivating. Pearl millet, used in this experiment was the short season, called Nirmal 9, while cowpea used was landrace of Bam pour.

Main-plots comprised four treatments of Fe fertilizer foliar spraying: no foliar fertilizer (municipal water spraying), foliar fertilization with Nano chelated iron (containing 38% Fe) in a dose of 1g l^{-1} (1‰); foliar fertilization with Nano chelated iron in a dose of 2 g l^{-1} (2‰); and foliar fertilization with Nano chelated iron in a dose of 3 g l^{-1} (3‰). Subplot treatments consisted of (a) sole cowpea (20 cowpea plant m^{-2}); (b)sole millet (20 millet plant m^{-2}); (c) 100% millet + 40% cowpea (20 millet plant m^{-2} + 8 cowpea plant m^{-2}); (d) 100% millet + 60% cowpea (20 millet plant m^{-2} + 12 cowpea plant m^{-2}); (e) 100% millet + 80% cowpea (20 millet plant m^{-2} + 16 cowpea plant m^{-2}). The treatments were laid out in 3 × 3 m plots and both crops at both monocrop and intercrop was sown manually on July 4. Adjacent plots were isolated by a 0.5 m wide ridge, and the replications were isolated by a 2.0 m wide ridge.

A recommended rate of 100 kg P2O5 ha^{-1}as triple super phosphate and 75 kg K2O ha^{-1} as potassium sulfate along with half of the of 100 kg N as urea before sowing uniformly broadcasted. Another half of N fertilizer were given nearly 30 DAS. Irrigation scheduling was based on the soil moisture deficit in the root region with 5-day intervals. During the growth period all plots were weeded by hand and no herbicide or pesticide was applied to either crop.

Plant Sampling: At the end of growth five millet plants or five cowpea plants were sampled and plant height, number of leaf per plant and some yield attributes were recorded. At maturity, heads of millet and pods of cowpea were harvested from each plot, sun dried for approximately 10 days to around 10% moisture content, threshed and weighed to determine grain yield. Total vegetative above–ground dry matter was determined by collecting all remaining above ground biomass from the same plots.

Calculations and Statistics: Advantage of intercropping over mono-cropping was calculated for each plot using relative crowding coefficient and total relative value.

The relative crowding coefficient was calculated according to the equation 1 (Midya *et al.,* 2005);

$$RCC = (\frac{Yij}{Yii})/(\frac{Yji}{Yjj}) \quad (1)$$

Where Yii and Yjj is yield of millet and cowpea in intercropping, respectively.

The total relative value was calculated according the equation 2 (Midya*et al.,* 2005);

$$\text{TRY} = \frac{aP1+bP2}{\text{aM}} \quad (2)$$

where a and b is market price for millet and cowpea, respectively; P_1 and P_2 is economic yield for millet and cowpea, respectively.

Data were analysis using analysis of variance (ANOVA) technique. Tukey's range test was utilized for mean separation when F values were significant.

RESULTS AND DISCUSSION

Millet: The studied attributes of millet included plant height, number of leaves and yield components (number of spikes per plant, number of seeds per seed and 1000 grain weight) was greater in intercropping in comparison with the mono-cropping (Table 2). The greatest and the least quantity of this traits was observed at intercropping of millet + 20% cowpea and intercropping of millet + 60% cowpea, respectively. In addition to, total studied yield components influenced ($p \leq 0.01$) by nanochelated iron and the greatest plant components was achieved in a dose of 3‰ + millet sole culture (number of spikes per plant was 12.86, number of seeds per seed was 291.70 and 1000 grain weight was 6.30 g). Iron increases these parameters by stimulation of tillering and formation of leaves.

Results showed that number of leaves per millet plant in mono-cropping was 16 percent greater than other intercropping (Fig 1 and 2). The greater leaves number per plant was because of greater growth of plants in absence of competition under mono-cropping conditions. The greatest plant height was observed in spraying with a dose of 3‰ of nanochelated iron + millet sole culture (73.76 cm). Millet growth parameters decreased with decreasing share of millet in canopies.

Immense effect of iron fertilizer on spike number per unit area reported by Malakouti and Tehrani (2008). Ramroudi *et al.* (2011) reported that the greatest number of grains per spike was observed when plant sprayed with iron fertilizer. Obtained results from experiment of Mirzapour *et al.* (2005) revealed positive effects of micronutrients application on grain number in sunflower. Furthermore, iron application at vegetative and reproductive stages increased 1000 grain weight by increasing photosynthesis and transfer of photosynthetic materials to the main reservoirs of plant (Pazoki *et al.,* 2009). Kordestani *et al.* (2009) announced that application of iron increased grain weight in sesame over control. One-thousand grain weight increasing by application of micronutrients reported by Kamarki and Galavi (2012) in safflower and Ghafari Malayeri *et al.* (2012) in corn.

In all studied systems grain and biological yield of millet was greater in monoculture over intercropping. Biological yield of millet was greater by 24 percent compared with the intercropping. The greatest grain yield of millet was observed in spraying with a dose of 3‰ of nanochelated iron + millet sole culture (1021.3 kg ha^{-1}) while the lowest grain yield was attained at no sprayed plant + intercropping of millet + 20% cowpea (442.8 kg ha^{-1}). The lowest biological yield was observed in spraying with a dose of 3‰ of nanochelated iron + intercropping of millet + 20% cowpea (Table 2).

The positive effect of zinc, iron and copper on grain yield of grain corn have been reported in many studies (Khalili Mahale *et al.,* 2004). Goudarzi *et al.* (2014) reported significant effects of iron and zinc application on grain yield and yield components of corn. Ghafari Malayeri *et al.* (2012) in corn observed greater biological yield by micronutrient spraying.

Cowpea: Morphological traits of cowpea including plant height and leaf number per plant and yield related traits including (pod number per plant, grain number per pod, 100 grain weight, grain and biological yield) significantly influenced ($p \leq 0.01$) by cropping patterns and application of nanochelated iron (Table 3). Greatest plant height (335.66 cm), leaf number per plant (39.72), pod number per plant (14.33), grain number per pod (11.10), one-hundred grain weight (29.947 gr.m^{-2}), grain yield (991.2 kg ha^{-1}) and biological yield (3959.9 kg ha^{-1}) was observed in a dose of 3‰ + cowpea sole culture. The increasing effect of iron spraying was greater in cowpea monoculture in comparison with intercropping (Table 3). Spraying of iron at flowering stage increased pod number per plant through increase the shelf life of flowers and turn it into the pods (Marschner, 1995). A significant decrease in empty seed and increase in grain number per plant by application of iron was reported (Baghaei *et al.,* 2012). The possible reason for pod number per plant, greater competition between two crop for available environmental resources.

Grain and biological yield of cowpea in monoculture compared with intercropping increased by 25 and 47 percent, respectively. Application of Nano-iron increased grain and biological yield of cowpea in comparison with no application.

Intercropping indices: Intercropping-related indices including relative crowding coefficient and total relative value influenced significantly ($p \leq 0.01$) by cropping patterns and iron spraying. Results showed that total relative value was greater than unit, indicating economic benefit of intercropping over mono-cropping in both crops. The greatest total relative value achieved in intercropping of millet + 60% cowpea (2.48), while the lowest quantity of this parameter obtained in intercropping of millet + 20% cowpea (1.40) (Table 4). The results suggested that intercropping of millet-cowpea increased diversity of agroecosystem, improved production sustainability, and increase in economic efficiency and productivity of agricultural land use. The total relative value reported greater than unit in other researches (Rezaei-Chianeh *et al.,* 2011). Teifeh Nouri (2003) announced that total relative value in whole cropping patterns was greater than one.

The relative crowding coefficient define as the ability to compete one species with another species in the mixture. The lower relative crowding coefficient, the lower beneficiary of intercropping over mono-cropping. The greatest relative crowding coefficient was observed in intercropping of millet + 20% cowpea (1.07) and the lowest quantity of this parameter was observed in intercropping of millet + 40% cowpea (0.99). Land use efficiency increases under intercropping conditions occurred when inter-species completion is low and positive interaction is high (Anil *et al.,* 1998).

Table 1. Physicochemical properties of soil in experimental site (soil depth 0-30 cm)

Soil texture	Available potassium (ppm)	Available phosphorus (ppm)	Total nitrogen (%)	Organic carbon (%)	EC (dS.m^{-1})	Fe	Zn	Mn	pH
						ppm			
Sandy-loam	230	28.4	0.08	0.7	2.5	8.7	2.1	3.2	7.5

Table 2. Effects of cropping systems and Nano iron fertilizer on plant height and yield attributes of millet

Treatments		Plant height (cm)	Number of ears per plant	number of grains per spike	1000-seed weight (g)	Grain yield (ton.ha^{-1})	Biological yield (ton.ha^{-1})
3‰	Sole millet	73.76^{a}	12.86^{a}	379.56^{a}	6.30^{a}	1.0213^{a}	3.5630^{a}
	Millet+ 20% cowpea	68.78^{ab}	11.33^{b}	355.26^{b}	4.80^{cde}	0.7907^{f}	2.9809^{g}
	Millet+ 40% cowpea	57.58^{cd}	9.20^{cde}	341.43^{cd}	4.81^{cde}	0.8436^{e}	3.1782^{e}
	Millet+ 60% cowpea	52.84^{d}	8.83^{def}	351.56^{bc}	4.71^{de}	0.8537^{b}	3.5246^{b}
2‰	Sole millet	65.60^{acd}	11.00^{b}	344.00^{cd}	5.29^{b}	0.8230^{c}	3.5254^{b}
	Millet+ 20% cowpea	60.51^{bcd}	9.83^{c}	343.56^{def}	5.18^{bc}	0.6165^{i}	2.8789^{h}
	Millet+ 40% cowpea	66.63^{abc}	8.33^{efgh}	319.44^{hi}	4.76^{de}	0.7581^{g}	3.0552^{f}
	Millet+ 60% cowpea	66.71^{abc}	8.73^{defg}	338^{def}	4.65^{de}	0.8778^{d}	3.4852^{c}
1‰	Sole millet	66.43^{abc}	9.40^{cd}	330.76^{efg}	5.05^{bcd}	0.8779^{d}	3.4814^{c}
	Millet+ 20% cowpea	67.75^{ab}	7.73^{hijk}	316.93^{i}	4.74^{de}	0.5713^{j}	2.6289^{j}
	Millet+ 40% cowpea	67.66^{ab}	8.06^{fghij}	320.50^{ghi}	4.65^{de}	0.6229^{i}	2.9875^{g}
	Millet+ 60% cowpea	59^{bcd}	7.86^{ghijk}	329.13^{fgh}	4.82^{cde}	0.7767^{fg}	3.2788^{d}
Control	Sole millet	63.98^{bc}	8.13^{fghi}	318.96^{hi}	4.60^{e}	0.7732^{fg}	3.1601^{e}
	Millet+ 20% cowpea	59.55^{bcd}	7.40^{ijk}	303.26^{j}	4.70^{ed}	0.4428^{k}	2.5345^{k}
	Millet+ 40% cowpea	60.68^{bcd}	7.20^{jk}	291.70^{k}	4.45^{e}	0.5555^{j}	2.7356^{i}
	Millet+ 60% cowpea	53.35^{d}	7.03^{k}	311.00^{ij}	4.43^{e}	0.6905^{h}	2.9777^{g}

Means in each column follow by similar letter(s) are not significantly different at 5% probability level, using Tukey.

Table 3. Effects of cropping systems and Nano iron fertilizer on plant height and yield attributes of cowpea.

Treatments		Biological yield (ton.ha^{-1})	Grain yield (ton.ha^{-1})	100-seed weight (g)	Number of seeds pod	Number of pods	Plant height (cm)
3‰	Sole cowpea	35.66^{a}	14.33^{a}	11.10^{a}	29.947^{a}	0.9912^{a}	3.9599^{a}
	Millet+ 20% cowpea	27.00^{bcde}	13.36^{abc}	9.00^{bcd}	27.429^{abcd}	0.7125^{f}	3.2892^{g}
	Millet+ 40% cowpea	27.66^{bcde}	10.86^{d}	7.13^{efg}	23.319^{fg}	0.7789^{e}	3.4935^{d}
	Millet+ 60% cowpea	32.33^{ab}	12.46^{bcd}	9.00^{bcd}	25.527^{def}	0.8895^{c}	3.6946^{b}
2‰	Sole cowpea	34.33^{a}	13.93^{ab}	10.16^{ab}	29.255^{ab}	0.9323^{b}	3.5698^{c}
	Millet+ 20% cowpea	26.66^{de}	8.93^{e}	6.60^{fgh}	24.679^{defg}	0.6659^{g}	2.9815^{j}
	Millet+ 40% cowpea	29.33^{bcd}	13.73^{ab}	9.46^{bc}	27.376^{abcd}	0.7803^{e}	3.2832^{g}
	Millet+ 60% cowpea	32.00^{ab}	11.93^{cd}	7.10^{efg}	23.511^{efg}	0.8538^{d}	3.3356^{f}
1‰	Sole cowpea	24.00^{efg}	13.86^{ab}	8.60^{cd}	29.714^{a}	0.8457^{d}	3.3975^{e}
	Millet+ 20% cowpea	28.66^{bcde}	11.06^{d}	6.06^{fgh}	28.545^{abc}	0.5384^{i}	2.7481^{k}
	Millet+ 40% cowpea	23.00^{cde}	11.73^{cd}	8.80^{cd}	22.215^{g}	0.6724^{g}	2.9746^{j}
	Millet+ 60% cowpea	31.66^{abc}	11.73^{cd}	7.86^{de}	26.260^{cde}	0.7848^{e}	3.2550^{h}
Control	Sole cowpea	24.00^{efg}	11.73^{cd}	7.23^{ef}	26.398^{bcde}	0.7333^{f}	3.1698^{i}
	Millet+ 20% cowpea	21.66^{fg}	9.13^{e}	6.66^{efgh}	23.946^{efg}	0.4641^{j}	2.4964^{m}
	Millet+ 40% cowpea	24.66^{efg}	11.13^{d}	5.93^{gh}	24.420^{efg}	0.5267^{i}	2.6481^{l}
	Millet+ 60% cowpea	19.33^{g}	8.43^{e}	5.46^{h}	22.533^{g}	0.6226^{h}	2.9786^{j}

Means in each column follow by similar letter(s) are not significantly different at 5% probability level, using Tukey.

Table 4- Intercropping-related indices in millet- cowpea intercropping.

Treatments		Relative value total	Relative congestion Index
3‰	Millet+ 20% cowpea	1.93d	1.07a
	Millet+ 40% cowpea	2.09c	1.05ab
	Millet+ 60% cowpea	2.38ab	1.04abc
2‰	Millet+ 20% cowpea	1.86d	0.93fg
	Millet+ 40% cowpea	2.23bc	0.97def
	Millet+ 60% cowpea	2.48a	1.03abc
1‰	Millet+ 20% cowpea	1.66e	1.02bcd
	Millet+ 40% cowpea	1.87d	0.90g
	Millet+ 60% cowpea	2.37ab	0.96ef
Control	Millet+ 20% cowpea	1.40f	0.90g
	Millet+ 40% cowpea	1.85d	0.99cde
	Millet+ 60% cowpea	2.23bc	1.05ab

Means in each column follow by similar letter(s) are not significantly different at 5% probability level, using Tukey.

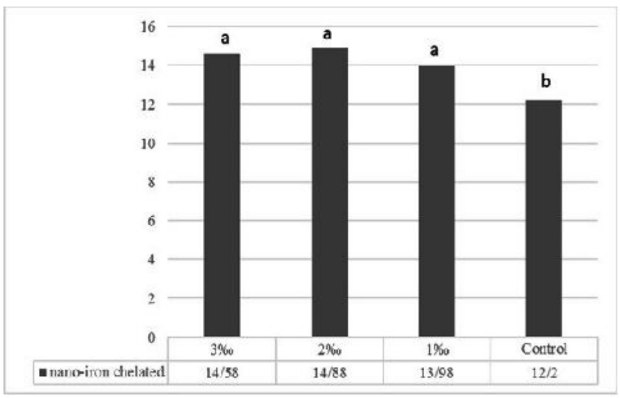

Fig 1. Effects of nano-iron fertilizer on leaf number per millet plant. Similar letter(s) are not significantly different at 5% probability level, using Tukey.

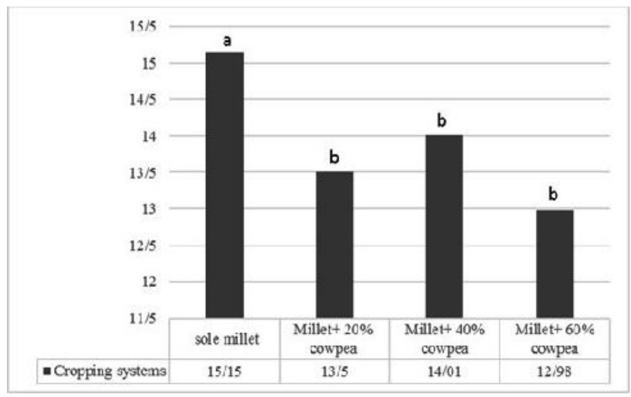

Fig 2. Effects of cropping systems on leaf number per millet plant. Similar letter(s) are not significantly different at 5% probability level, using Tukey.

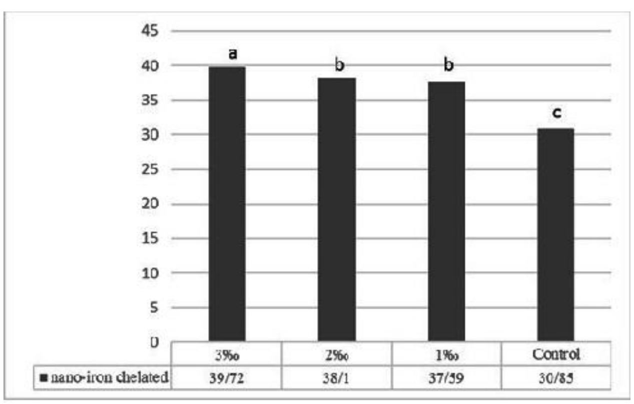

Fig 3. Effects of nano-iron fertilizer on leaf number per cowpea plant. Similar letter(s) are not significantly different at 5% probability level, using Tukey.

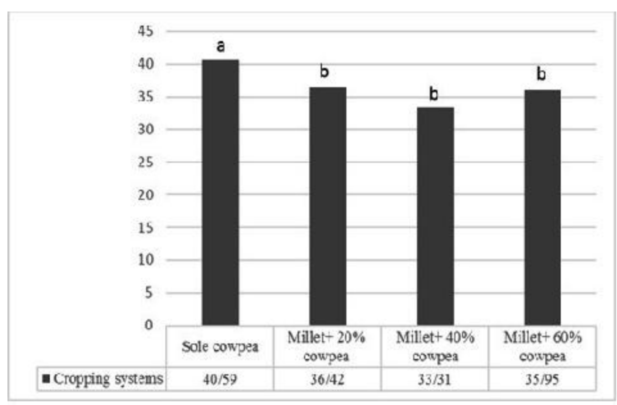

Fig 4. Effects of cropping systems on leaf number per cowpea plant. Similar letter(s) are not significantly different at 5% probability level, using Tukey.

Conclusion: The experimental results suggested that spraying of nanochelated iron increased yield and yield components of millet- cowpea intercropping. The concentration of 3‰ had the greatest influence. Sole culture had greater yield compared with the intercropping. The significant effect of spraying on yield and yield components of both crops indicated nano fertilizer spraying could be considered as an effective management strategy to increase the efficiency of nutrients to achieve sustainable agricultural goals and increase yield. In general, and with regard to poor soil of the region Nano iron fertilizer could be placed in crop nutrition program.

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