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Effects of intercropping, *Bradyrhizobium* inoculation and chicken manure fertilisation on the chemical composition and physical characteristics of soybean seed

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ABSTRACT

A field experiment was carried out to investigate the effect of two *Bradyrhizobium* strains (local and imported), chicken manure fertilisation (7 t/ha) and intercropping with sorghum on the chemical composition and physical characteristics of soybean seed. For both monocropping and intercropping systems, moisture content slightly increased for both systems and for all treatments, while ash, fibre and carbohydrate contents fluctuated for both systems and treatments. The protein content of the seeds was significantly ($p \leqslant 0.05$) increased for all treatments. Tannin content was increased significantly ($p \leqslant 0.05$) with a concomitant decrease in protein digestibility for both systems and for all treatments. The seed weight (100 seeds), hydration coefficient and cookability were increased for all treatments. Mineral composition of the seeds was increased and the increment varied with different treatments.

1. Introduction

The importance of legumes as food lies primarily in their high protein content, on average 20–25%. Soybean (*Glycine max* (L.)) is a unique crop, containing 32–45% protein. Seeds are used as a raw material for the production of top-quality protein and dry oil, varnishes, soaps, plastics, candies, shampoos, pesticides, paints, disinfectants, strong glues and adhesives. Soybean is an excellent source of low-cost protein, which biologically and nutritionally resembles animal proteins. Grain legumes such as cowpea and soybean are good nitrogen fixers, and they usually meet all of their nitrogen needs other than that absorbed from the soil (Lindet, Maria, & Norma, 1997). The nitrogen will be available to the companion plants in intercropping system or to the succeeding plants in crop rotation (Giller & Wilson, 1993). Inoculation of soybean by *Bradyrhizobium japonicum* significantly increased nodulation and yield (Okereke & Onochie, 1996). Manure is a readily available organic source of essential plant nutrients. It is used primarily as a source of plant nutrients (Mullins, Bendfeldt, & Clarik, 2002). Moreover, manure is a source of energy for soil biota and thus influences many of the biological processes of soil (Woomer & Swift, 1991). Chicken manure is considered to have fertilising properties, intermediate between mineral fertilisers and farmyard manure, and it has an appreciable residual effect (Woomer & Swift, 1991). Soybean can restore soil fertility by building up the soil nitrogen through biological nitrogen fixation. The nitrogen will be available to the companion plants in an intercropping system or to the succeeding plants in crop rotation (Giller & Wilson, 1993). Most of the available reports studied the transfer of nitrogen from soybean plant, the accumulation of the nitrogen in the companion plants and crop productivity (Döbereiner, 1997). Moreover, crop productivity can be increased by the application of chemical, organic and biological fertilisers. Biofertilisation of soybean with effective strains of rhizobia will enhance nitrogen fixation and improve crop yield (Kumaga, Owusu-Ensawa, & Danso, 1998). Several trials, such as urea fertilisation (Krishnan, Bennett, Kim, Krishnan, & Mawhinney, 2005; Takahashi, Ohtake, Hattori, Nagumo, & Ohyama, 2006) agricultural practices (Temperly & Borges, 2006) and environmental effects (Hou, Ablett, Pauls, & Rajcan, 2006) were examined, to improve the composition and seed quality of soybean. Very few reports focused on the effect of *Rhizobium* inoculation and chicken manure fertilisation on the chemical composition and physical characteristics of leguminous seeds (Elsheikh, 2001). Therefore, the present study was conducted to assess the effect of intercropping, inoculation and chicken manure fertilisation on the chemical composition and physical properties of soybean seed.

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2. Materials and methods

2.1. Materials

Bradyrhizobium strain TAL 377 was supplied by NiFTAL Project, Paia, Hawaii, USA, where Isolate-2 was locally isolated from nodules of soybean plants and has been chosen as the best isolate out of 14 local isolates in a previous screening experiment. The strains were maintained at 4 °C on yeast mannitol agar (YEMA) slopes. Charcoal-based inoculum was used to inoculate the seeds. Soybean (*Glycine max* (L.) Merr.) seeds, variety "Jupiter", were obtained from Arab Corporation for Agricultural Investment and Development. Sorghum (*Sorghum bicolor* L.; Moench.) seeds, variety "Dabar", were obtained from the local market. Unless otherwise stated, all chemicals used in this study were of reagent grade.

2.2. Experiments

Soybean seeds were planted in Abu Usher region (latitude 14°55′N and longitude 33°11′E) during 1998/99. The soil was clay loam (69.4% clay, 10% silt, and 20.6% sand) with a pH of 7.9. The total nitrogen was 0.11% and phosphorus was 0.1%. Soybean seeds were planted alternatively with sorghum seeds, three holes of soybean followed by three holes of sorghum. In the monocropping system, soybean seeds were planted 10 cm apart with three seeds per hole on one side of the ridge. In the intercropping system, soybean seeds were planted 20 cm apart from sorghum. The experiment was arranged in split-plot design with four replicates. The main plots had the following treatments:

(1) Uninoculated control;
(2) inoculated with *Bradyrhizobium* strain TAL 377;
(3) inoculated with *Bradyrhizobium* strain Isolate-2;
(4) uninoculated plus 7 t/ha chicken manure;
(5) inoculated with *Bradyrhizobium* strain TAL 377 plus 7 t/ha chicken manure;
(6) inoculated with Isolate-2 plus 7 t/ha chicken manure.

The monocropping system and the intercropping system were assigned to the subplots. Samples of the collected soybean seeds were cleaned from impurities, washed with distilled water, sun dried and then ground to pass a 0.4 mm mesh screen. The powder was used for the analytical tests.

2.3. Methods

2.3.1. Chemical composition determination

Methods of AOAC (1984) were followed in the determination of crude protein, moisture, ash, fat and crude fibre contents. Carbohydrate was calculated by difference.

2.3.2. In vitro protein digestibility determination

In vitro protein digestibility (IVPD) was determined using the modified method of Manjula and John (1991).

2.3.3. Tannin content determination

Tannin content was estimated quantitatively using the modified vanillin HCl method (Price, Scoyoc, & Butler, 1978).

2.3.4. Hydration coefficient

From each plot 100 seeds were selected randomly, weighed and soaked in tap water at a ratio of 1:4 for 16 h. The hydration coefficient percentage was calculated for each sample as follows:

$$\text{Hydration coefficient}\% = \frac{\text{Weight of soaked seeds}}{\text{Initial weight}} \times 100$$

2.3.5. Cookability

Twenty grams of soybean seeds were cooked separately in 200 ml of tap water at 110 °C for 30 min. The sample was reweighed after cooking. Cookability was calculated as follows:

$$\text{Cookability}\% = \frac{\text{Weight after cooking} - \text{initial weight}(20\ \text{g})}{\text{Initial weight}(20\ \text{g})} \times 100$$

2.3.6. Minerals determination

Minerals (Ca, K, Mg, Mn, Na, Zn, Cu, Co, Fe) were determined by atomic absorption spectroscopy. The dry ashing procedure was used for these determinations (Pearson, 1981).

2.3.7. Statistical analysis

Least significant difference was used to compare between treatment means. Duncan's Multiple Range Tests was used to determine the level of significance, which was accepted at $p \leqslant 0.05$.

3. Results and discussion

3.1. Chemical composition

3.1.1. Moisture content

The average moisture content of monocropped soybean seeds was found to range from 7.0% to 7.6% and from 7.4% to 9.5% for the intercropped soybean seeds (Table 1). The moisture content of either intercropped or monocropped soybean seeds was not significantly affected by any treatment. However, Elsheikh and Ahmed (2000) reported that, the moisture content of faba bean was significantly ($p \leqslant 0.05$) increased by inoculation, with no effect of intercropping.

3.1.2. Ash content

Bradyrhizobium inoculation by either strain TAL 377 or Isolate-2 did not affect the ash content of monocropped soybean seeds. For intercropped soybean, inoculation with Isolate-2 significantly ($p \leqslant 0.05$) increased the ash content of the seeds. However, no effect was detected by inoculation with TAL 377 (Table 1). Application of chicken manure to monocropped or intercropped soybean seeds had no significant effect on ash content. However, addition of manure to soybean plants inoculated with Isolate-2 showed significant effect on the ash content of the seeds. Similarly, in a

Table 1
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on moisture, ash and fibre contents (%) of soybean seeds

Treatment	Moisture	Ash	Fibre
Monocropping system			
Control	7.00 (±0.17)^{a}	3.32 (±0.48)^{ab}	5.84 (±0.24)^{a}
TAL 377	7.25 (±0.32)^{ab}	3.82 (±0.44)^{back}	5.26 (±0.18)^{a}
Isolate-2	7.32 (±0.44)^{ab}	4.00 (±0.19)^{abcde}	4.88 (±0.16)^{a}
7 t/ha manure	7.43 (±0.36)^{ab}	3.64 (±0.35)^{abc}	5.58 (±0.12)^{a}
7 t/ha manure + TAL 377	7.64 (±0.38)^{ab}	4.84 (±0.45)^{bcde}	4.62 (±0.38)^{a}
7 t/ha manure + Isolate-2	7.52 (±0.34)^{ab}	5.55 (±0.47)^{e}	4.44 (±0.48)^{a}
Mean	7.36	4.30	5.10
Intercropping system			
Control	7.42 (±0.24)^{ab}	3.28 (±0.40)^{ab}	5.63 (±0.21)^{a}
TAL 377	7.90 (±0.25)^{ab}	4.70 (±0.43)^{abcde}	5.13 (±0.16)^{a}
Isolate-2	8.21 (±0.26)^{ab}	5.40 (±0.12)^{de}	4.49 (±0.24)^{a}
7 t/ha manure	8.63 (±0.13)^{ab}	3.12 (±0.16)^{a}	5.36 (±0.28)^{a}
7 t/ha manure + TAL 377	8.88 (±0.24)^{ab}	4.50 (±0.19)^{abcde}	4.57 (±0.39)^{a}
7 t/ha manure + Isolate-2	9.50 (±0.30)^{b}	5.00 (±0.24)^{cde}	4.32 (±0.29)^{a}
Mean	8.42	4.33	4.97
LSD (5%) for means	0.99	0.73	0.73

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

previous report, application of chicken manure significantly increased the ash content of faba bean seeds (Elsheikh & Elzidany, 1997a).

3.1.3. Fibre content

Inoculation with each of the two strains and application of chicken manure to inoculated or uninoculated soybean seeds had no significant effect on fibre content of both monocropped and intercropped soybean seeds (Table 1). The fibre content of soybean seeds was found to be in the range of 4.3–5.8%.

3.1.4. Protein content

Inoculation with each of the two strains significantly ($p \leqslant 0.05$) increased the protein content of both monocropped and intercropped soybean seeds (Table 2). There was no significant difference between the two strains within each cropping system and between the two systems. The increase in protein level by inoculation in the seeds of several leguminous crops has been reported (Elsheikh, 2001). Application of chicken manure to uninoculated plants significantly increased the protein content of monocropped seeds. Furthermore, application of chicken manure to inoculated plants had a significant effect on protein content of monocropped and intercropped soybean. However, the highest value of protein was 48.7%, reported for monocropped seeds inoculated with Isolate-2 and fertilized by chicken manure. The beneficial effect of chicken manure on the protein content maybe attributed to the increment of nitrate nitrogen in the soil. Soybean seed protein was not greatly reduced by intercropping. However, contradicting results were reported by Elsheikh and Ahmed (2000), where the protein content of faba bean seeds was significantly enhanced by intercropping with maize.

3.1.5. Fat content

Bradyrhizobium inoculation by either strain TAL 377 or Isolate-2 significantly ($p \leqslant 0.05$) increased fat content of soybean seeds in both monocropping and intercropping systems (Table 2). Application of chicken manure to uninoculated plants significantly increased the fat content of both monocropped and intercropped soybean seeds. Similarly, inoculation with Isolate-2 or TAL 377 and manuring significantly ($p \leqslant 0.05$) increased the fat content of soybean in monocropped and intercropped seeds. The fat content of soybean seeds was found to be in the range of 14.2–22.8%. Generally, fat content of soybean seeds was reduced by intercropping, although the reduction was not significant. Wahua and Miller (1978) reported that oil content was reduced by 8% and 3% for soybean intercropped with tall and dwarf sorghum, respectively. Moreover, Hou et al. (2006) showed that environmental factors affected the composition of fatty acids (saturated and unsaturated) in soybean seed oil.

3.1.6. Carbohydrates content

Inoculation with each of the two strains significantly ($p \leqslant 0.05$) decreased the carbohydrate content for both monocropped and intercropped soybean seeds (Table 2). Generally, the carbohydrate content in the seeds of the leguminous crops was found to decrease with *Rhizobium* inoculation (Elsheikh, 2001). Chicken manure decreased the carbohydrate content of soybean seeds in both cropping systems, whether inoculated or uninoculated. This reduction in carbohydrate content could be attributed to the increment in protein content resulting from higher levels of available nitrogen.

3.2. Tannin content

Bradyrhizobium inoculation significantly ($p \leqslant 0.05$) increased the tannin content of both monocropped and intercropped soybean seeds over the control (Table 3). However, application of chicken manure showed no significant effect on tannin content in both cropping systems.

3.3. In vitro protein digestibility (IVPD)

None of the treatments had a positive significant effect on the in vitro protein digestibility of soybean seeds in both cropping systems (Table 3). IVPD was found to be in the range of 82.2–90.5%. The IVPD was decreased over the control, which might be due to increase in the tannin content, which was found to have an adverse effect on IVPD. However, *Bradyrhizobium* inoculation was observed to increase the IVPD of faba bean seeds (Elsheikh & Ahmed, 2000) and groundnut (Elsheikh & Mohamedzein, 1998).

3.4. 100-Seed Weight

Inoculation with TAL 377 or Isolate-2 significantly ($p \leqslant 0.05$) increased 100-seed weight for both monocropped and intercropped

Table 2
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on protein, fat and carbohydrate contents (%) of soybean seeds

Treatment	Protein	Fat	Carbohydrate
Monocropping system			
Control	35.24 (±0.29)^{a}	14.57 (±0.30)^{a}	43.03 (±2.5)^{c}
TAL 377	43.81 (±0.33)^{bcd}	21.83 (±0.18)^{b}	18.03 (±2.4)^{ab}
Isolate-2	45.87 (±0.25)^{cd}	22.80 (±0.17)^{b}	15.13 (±3.6)^{ab}
7 t/ha manure	42.94 (±0.27)^{bcd}	20.45 (±0.44)^{b}	20.10 (±2.0)^{ab}
7 t/ha manure + TAL 377	47.25 (±0.23)^{cd}	21.17 (±0.31)^{b}	14.48 (±3.1)^{ab}
7 t/ha manure + Isolate-2	48.66 (±0.62)^{d}	21.62 (±0.29)^{b}	12.21 (±1.5)^{ab}
Mean	43.96	20.41	20.00
Intercropping system			
Control	36.62 (±0.30)^{ab}	14.16 (±0.40)^{a}	32.89 (±3.2)^{c}
TAL 377	44.35 (±0.48)^{cd}	22.05 (±0.18)^{b}	15.79 (±3.4)^{ab}
Isolate-2	45.25 (±0.32)^{cd}	21.48 (±0.15)^{b}	14.87 (±3.2)^{ab}
7 t/ha manure	40.53 (±0.50)^{abc}	20.85 (±0.12)^{b}	21.51 (±2.0)^{b}
7 t/ha manure + TAL 377	48.22 (±0.15)^{cd}	21.48 (±0.16)^{b}	12.35 (±2.1)^{ab}
7 t/ha manure + Isolate-2	48.56 (±0.12)^{d}	21.56 (±0.30)^{b}	11.06 (±1.4)^{a}
Mean	43.92	20.26	18.11
LSD (5%) for means	3.51	0.81	4.49

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

Table 3
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on percent IVPD, tannin and 100-seed weight of soybean seeds

Treatment	IVPD	Tannin	100-Seed weight
Monocropping system			
Control	90.5 (±3.1)^{b}	0.034 (±0.009)^{a}	9.41 (±0.50)^{a}
TAL 377	87.8 (±2.6)^{ab}	0.079 (±0.014)^{bc}	12.6 (±0.15)^{bcd}
Isolate-2	86.2 (±2.2)^{ab}	0.093 (±0.004)^{cd}	13.0 (±0.90)^{bcd}
7 t/ha manure	89.0 (±1.5)^{ab}	0.052 (±0.015)^{ab}	10.6 (±0.74)^{abc}
7 t/ha manure + TAL 377	84.7 (±2.1)^{ab}	0.089 (±0.005)^{cd}	13.3 (±0.65)^{cd}
7 t/ha manure + Isolate-2	83.2 (±2.3)^{ab}	0.12 (±0.011)^{d}	13.8 (±0.29)^{cd}
Mean	86.9	0.078	12.1
Intercropping system			
Control	89.7 (±1.6)^{ab}	0.044 (±0.015)^{a}	8.77 (±0.60)^{a}
TAL 377	86.7 (±1.7)^{ab}	0.076 (±0.008)^{bc}	12.8 (±0.43)^{bcd}
Isolate-2	85.3 (±2.8)^{ab}	0.082 (±0.009)^{bc}	13.2 (±0.31)^{cd}
7 t/ha manure	88.2 (±1.4)^{ab}	0.050 (±0.005)^{ab}	9.81 (±0.71)^{ab}
7 t/ha manure + TAL 377	83.8 (±2.6)^{ab}	0.100 (±0.007)^{cd}	13.6 (±1.08)^{cd}
7 t/ha manure + Isolate-2	82.2 (±2.3)^{ab}	0.130 (±0.011)^{d}	13.9 (±0.29)^{cd}
Mean	86.0	0.083	12.1
LSD (5%) for means	3.69	0.021	1.35

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

soybean seeds (Table 3). There was no significant difference between the two strains. Application of chicken manure to uninoculated plants had no significant effect on 100-seed weight of soybean seeds in both cropping systems. However, application of chicken manure and inoculation significantly increased 100-seed weight of soybean seeds in both cropping systems over the control. Intercropping increased 100-seed weight of soybean seeds but the increment was not significant.

3.5. Hydration Coefficient

Inoculation with Isolate-2 significantly ($p \leqslant 0.05$) increased the hydration coefficient of soybean seeds in both cropping systems (Table 4). Addition of chicken manure and inoculation with Isolate-2 resulted in higher increment that was significantly different from the control. Inoculation with TAL 377 did not significantly affect the hydration coefficient of soybean seeds in both cropping systems. Generally, intercropping did not affect the hydration coefficient of soybean seeds.

3.6. Cookability

Inoculation with either TAL 377 or Isolate-2 or manure fertilisation had no effect on the cookability of soybean seeds in intercropping and monocropping systems (Table 4). It was previously reported that chicken manure significantly increased the cookability in the presence or absence of *Rhizobium* inoculation (Elsheikh & Elzidany, 1997b).

3.7. Minerals contents

Minerals contents of soybean seeds varied in different treatments (Tables 5–7). Inoculation with TAL 377 significantly ($p \leqslant 0.05$) increased Ca, Cu, Fe, K, Mn, Na and Zn contents of monocropped soybean and insignificantly increased Mg and Zn of intercropped soybean seeds. Inoculation with Isolate-2 significantly increased Ca, Co, Cu, Fe, K, Mn, Zn and Na contents of monocropped seeds. For intercropped soybean seeds, all minerals increased.

Table 4
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on percent hydration coefficient and cookability of soybean seeds

Treatment	Hydration coefficient	Cookability
Monocropping system		
Control	181 (±1.96)^{a}	20.0 (±1.86)^{a}
TAL 377	213 (±2.53)^{abcd}	21.4 (±0.83)^{a}
Isolate-2	218 (±2.16)^{bcd}	21.8 (±1.95)^{a}
7 t/ha manure	186 (±0.87)^{ab}	20.6 (±0.91)^{a}
7 t/ha manure + TAL 377	226 (±0.54)^{cd}	20.1 (±1.22)^{a}
7 t/ha manure + Isolate-2	230 (±0.86)^{d}	23.7 (±1.61)^{a}
Mean	209	21.3
Intercropping system		
Control	182 (±0.51)^{a}	20.5 (±1.60)^{a}
TAL 377	215 (±0.74)^{abcd}	21.6 (±0.96)^{a}
Isolate-2	221 (±2.24)^{bcd}	22.6 (±1.63)^{a}
7 t/ha manure	191 (±0.96)^{abc}	20.8 (±0.81)^{a}
7 t/ha manure + TAL 377	228 (±1.86)^{d}	23.5 (±0.66)^{a}
7 t/ha manure + Isolate-2	233 (±2.10)^{d}	23.9 (±0.83)^{a}
Mean	212	22.1
LSD (5%) for means	16.4	2.83

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

Table 5
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on calcium, cobalt and copper content (mg/100 g) of soybean seeds

Treatment	Calcium	Cobalt	Copper
Monocropping system			
Control	330 (±2.00)^{a}	0.12 (±1.52)^{a}	1.94 (±0.32)^{a}
TAL 377	366 (±1.50)^{c}	0.23 (±1.52)^{abcd}	2.64 (±0.41)^{c}
Isolate-2	370 (±1.51)^{c}	0.33 (±0.91)^{d}	3.1 (±0.26)^{d}
7 t/ha manure	360 (±1.26)^{bc}	0.15 (±1.73)^{ab}	2.15 (±0.13)^{bc}
7 t/ha manure + TAL 377	370 (±1.29)^{c}	0.17 (±1.72)^{abc}	2.15 (±0.43)^{bc}
7 t/ha manure + Isolate-2	385 (±1.54)^{c}	0.24 (±1.52)^{abcd}	2.25 (±0.47)^{bc}
Mean	364	0.21	2.38
Intercropping system			
Control	315 (±0.77)^{ab}	0.12 (±1.70)^{a}	1.27 (±0.35)^{b}
TAL 377	378 (±0.90)^{c}	0.26 (±1.50)^{bcd}	2.26 (±0.55)^{bc}
Isolate-2	388 (±0.64)^{c}	0.45 (±1.88)^{e}	2.46 (±0.17)^{c}
7 t/ha manure	365 (±1.64)^{c}	0.16 (±1.51)^{abc}	2.16 (±0.88)^{bc}
7 t/ha manure + TAL 377	383 (±1.51)^{c}	0.20 (±1.25)^{abcd}	2.34 (±0.15)^{bc}
7 t/ha manure + Isolate-2	395 (±1.08)^{c}	0.29 (±1.30)^{cd}	2.57 (±0.75)^{c}
Mean	370	0.25	2.18
LSD (5%) for means	16.1	0.05	0.23

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

Table 6
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on iron, potassium and magnesium contents (mg/100 g) of soybean seeds

Treatment	Iron	Potassium	Magnesium
Monocropping system			
Control	8.45 (±0.13)^{a}	1183 (±3.68)^{a}	219 (±3.81)^{ab}
TAL 377	11.4 (±0.28)^{d}	1910 (±3.63)^{g}	228 (±2.17)^{ab}
Isolate-2	11.2 (±0.16)^{d}	2180 (±2.42)^{h}	240 (±3.41)^{abcd}
7 t/ha manure	9.25 (±0.38)^{b}	1282 (±2.04)^{c}	224 (±1.43)^{ab}
7 t/ha manure + TAL 377	11.1 (±0.14)^{d}	1600 (±3.22)^{e}	249 (±2.84)^{bcd}
7 t/ha manure + Isolate-2	11.5 (±0.18)^{d}	1782 (±3.72)^{f}	245 (±2.50)^{abcd}
Mean	10.5	1656	234
Intercropping system			
Control	8.35 (±0.19)^{a}	1195 (±2.72)^{ab}	215 (±3.61)^{a}
TAL 377	9.72 (±0.10)^{bc}	1316 (±0.81)^{c}	236 (±2.57)^{abcd}
Isolate-2	10.2 (±0.22)^{c}	1516 (±3.21)^{d}	245 (±1.50)^{abcd}
7 t/ha manure	9.55 (±0.11)^{bc}	1266 (±2.63)^{bc}	229 (±3.58)^{cd}
7 t/ha manure + TAL 377	11.2 (±0.12)^{d}	1850 (±2.25)^{fg}	259 (±2.96)^{cd}
7 t/ha manure + Isolate-2	11.7 (±0.35)^{d}	2150 (±3.76)^{h}	265 (±2.73)^{d}
Mean	10.1	1549	242
LSD (5%) for means	0.34	38.2	13.9

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

Table 7
Effect of intercropping (sorghum/soybean), *Bradyrhizobium* inoculation and chicken manure on manganese, sodium and zinc contents (mg/100 g) of soybean seeds

Treatment	Manganese	Sodium	Zinc
Monocropping system			
Control	2.62 (±0.19)^{ab}	7.55 (±0.34)^{a}	2.02 (±0.14)^{a}
TAL 377	3.80 (±0.05)^{g}	12.6 (±0.22)^{ef}	4.30 (±0.16)^{de}
Isolate-2	3.70 (±0.02)^{fg}	13.9 (±0.24)^{f}	4.60 (±0.13)^{e}
7 t/ha manure	3.00 (±0.21)^{bcd}	9.75 (±0.56)^{bc}	2.50 (±0.44)^{a}
7 t/ha manure + TAL 377	3.25 (0.28)^{cde}	11.5 (±0.36)^{cde}	3.55 (±0.12)^{bc}
7 t/ha manure + Isolate-2	3.35 (±0.05)^{def}	12.1 (±0.12)^{def}	3.75 (±0.10)^{bcd}
Mean	3.29	11.2	3.45
Intercropping system			
Control	2.53 (±0.14)^{a}	7.25 (0±.26)^{a}	2.00 (±0.06)^{a}
TAL 377	3.15 (±0.13)^{cde}	10.3 (±0.63)^{bcd}	2.30 (±0.15)^{a}
Isolate-2	3.30 (±0.06)^{def}	12.0 (±0.34)^{def}	2.25 (±0.14)^{a}
7 t/ha manure	2.85 (±0.13)^{abc}	9.00 (±0.36)^{ab}	3.45 (±0.18)^{b}
7 t/ha manure + TAL 377	3.50 (±0.12)^{efg}	11.2 (±0.24)^{cde}	3.85 (±0.14)^{bcd}
7 t/ha manure + Isolate-2	3.45 (±0.05)^{efg}	12.2 (±0.44)^{def}	4.15 (±0.41)^{cde}
Mean	3.13	10.3	3.00
LSD (5%) for means	0.18	1.01	0.31

Values are means (±SD). Means sharing similar letter(s) within each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

Application of chicken manure to uninoculated monocropped soybean seeds significantly increased Fe, K and Na, while for intercropped seeds Ca, Fe, Mg and Zn were significantly increased. Inoculation with TAL 377 and addition of chicken manure significantly increased Cu, Fe, K, Mn, Na and Zn of soybean seeds in monocropping system, and Mg and Ca in intercropping system. Fertilisation of chicken manure and inoculation with Isolate-2 significantly increased Ca Na, Zn, Mn, K, Fe and Cu in monocropping system, in addition to Co in intercropping system. Generally, most of the minerals studied were significantly increased by inoculation. The effect of intercropping was mostly variable. Previously, Elsheikh and Ibrahim (1999) reported that inoculation with *Bradyrhizobium* strains significantly increased Ca, Mg, K and Zn content of five cultivars of guar seeds. Moreover, they reported that inoculation insignificantly affected Na, Mn, Co and Fe contents.

4. Conclusion

Both intercropping and inoculation altered the chemical composition of soybean. However, minerals content fluctuated and the increment or reduction induced by intercropping on mineral composition was not significant.

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