Availability of Mineral Nitrogen in Soil under Maize + Soybean Intercropping System

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A B S T R A C T

This field experiment was conducted during the kharif season of 2014 and 2015 at the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G) to find out the effect of crop arrangement and nutrient management on availability of nutrients under maize and soybean intercropping system. Treatments comprised of six cropping arrangements viz. sole maize (C₁), sole soybean (C₂), two replacement series of maize + soybean (2:2, C₃ and 2:4, C₄), two additive series in which two rows (C₅) and one row (C₆) of soybean were added in-between two rows of maize and four fertility levels viz. 125% recommended dose of fertilizer (RDF) (F₁), 100% RDF (F₂), 75% RDF (F₃) and 50% RDF (F₄). Two control plots; control₁ and control₂ (From the two additive series plots soybean rows were omitted and the space between paired row of maize were left fellow) were planted in order to calculate the amount of mineral nitrogen supplemented by soybean to maize. Results of this experiment show the higher availability of nutrients in soil under intercropping over sole plantation. Out of six crop arrangements 2:4 replacement series of maize and soybean showed the highest availability of NH₄⁺-N and NO₃⁻-N in soil and this was closely followed by maize + soybean 2:2 crop arrangement. However, the lowest availability of mineral nitrogen was observed from the sole soybean. Among different nutrient management the highest and lowest availability of aforesaid nutrients were reported in the treatment fertilized with 125% and 50% RDF, respectively. Intercropped treatments exhibited 10.76 and 8.39 per cent higher availability of NH₄⁺-N and 13.13 and 7 per cent higher availability NO₃⁻-N in soil in comparison to control₁ and control₂, respectively. Around 17.09 kg ha⁻¹ higher available mineral nitrogen (NH₄⁺-N + NO₃⁻-N) was reported under intercropping treatments than control plots. This additional amount of available NH₄⁺-N and NO₃⁻-N was supplied by the soybean through biological nitrogen fixation.

Introduction

Economic constraints among small scale farmers in India limit sole inorganic fertilizer use. Further, the use of fertilizer, pesticides and various synthetic chemicals leads to the degradation of cultivable land and natural resources. Thus it is necessary to find
additional sources of N that would embrace the smallholder socio-economic status. Cereal + grain legume intercropping is one of them. Growing of cereal with grain legume has not only gives higher yield but also has the potential to address the soil nutrient depletion on smallholder farms (Sanginga and Woomer, 2009). Maize and soybean are promising crops in aerable lands of Chhattisgarh besides rice as main crop in medium and low land situation. Intercropping of legumes in maize was found productive economically and energetically viable (Pandey et al., 2003) compared to either of the sole crops. Soybean is considered as an ideal crop for intercropping with maize owing to its comparative tolerance for shade and drought, efficient light utilization and less competitiveness for soil moisture (Wright et al., 1988).

Intercropping is a viable agronomic practice for stepping up the production of these crops from a unit of land besides sustaining the soil health through biological nitrogen fixation by soybean during a cropping period. Sustainable production of these crops requires a careful management of all nutrient sources available in a farm, particularly in maize based cropping systems. These include inorganic fertilizers and integration of legume crops in cereal based mono cropping (Wakene et al., 2007). Maize being an exhaustive crop requires high quantity of fertilizers, particularly nitrogenous. In intercropping systems, legumes can provide N for intercropped cereals through N transfer. Thus being a legume crop soybean is capable of supplying nitrogen for its growth and intercropped cereals through symbiotic nitrogen fixation, and hence reduces the need for expensive and environment polluting nitrogen fertilizer (Ning et al., 2012).

Transformation of added nitrogen through fertilizers, manures or biological nitrogen fixation into different forms of nitrogen in soil and their availability to crops depends on soil properties and nature of nitrogen sources added to soils. According to the research reports, more than 90 per cent of nitrogen in the soil is present in organic form and concentrations of inorganic form viz., nitrate nitrogen and ammonical nitrogen in soil at any given time is influenced by several soil factors. So to maintain the higher availability of nutrients in order to obtain the optimum yield from the intercropping system, there is need to take care of different types of competitions between the intercrops. Therefore, this experiment is an attempt to study the proper arrangement of component crops in order to avoid limitation of reduced plant population of base crop under traditional intercropping system and a careful management of all nutrient sources which includes inorganic fertilizers as well as the biologically fixed nitrogen provided by soybean to maize so that higher production unit-1 of land could be achieved.

Materials and Methods

Field experiment was conducted during the kharif season (July to October) of 2014 and 2015 at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur situated in central parts of Chhattisgarh and lies at latitude, longitude and altitude of 21°4’ N, 81°35’ E and 290.20 metres above mean sea level, respectively. The hybrid maize variety Hishell and soybean variety Jawahar Soybean 97-52 (JS 97-52) were used in the experiment. Soil of experimental site was caly (Vertisol) with neutral pH (7.50) and 0.26 dSm EC. Soil was low in nitrogen (175.61 kg ha-1) and phosphorus (10.74 kg ha-1) and potassium availability was medium (330.74 kg ha-1). The experiment was laid out in Factorial Randomised Block Design with one additional plot design. There were 3 replications and all of them were divided into 24 + 2 experimental treatments and each treatment was applied to a plot had an area of 38.4 m2. Maize and
soybean were spaced at a spacing of 60×20 cm² and 5×30 cm², respectively. Treatments comprised of six cropping arrangements viz. sole maize (C₁), sole soybean (C₂), maize + soybean in 2:2 (C₃) and 2:4 (C₄) rows in replacement series and two additive series (two rows of soybean (C₅) and one row of soybean (C₆) planted in-between two rows of maize and four fertility levels viz. 125% recommended dose of fertilizer (RDF) (F₁), 100% RDF (F₂), 75% RDF (F₃) and 50% RDF (F₄). Recommended dose of fertilizer used for maize was 110 kg N ha⁻¹, 60 P₂O₅ kg ha⁻¹ and 40 K₂O kg ha⁻¹ and for soybean was 20 N kg ha⁻¹, 60 P₂O₅ kg ha⁻¹ and 40 K₂O kg ha⁻¹. Analysis of availability of ammonium and nitrate nitrogen was done by Steam distillation method as suggested by Bremner and Keeney (1965). To find out the amount of nitrogen supplemented by soybean to maize we compared the mean availability of mineral nitrogen (Ammonium and nitrate) from 24 treatments and this was compared with control plots. For this comparison two control plots were taken in which the soybean rows planted in between paired maize rows (Under two additive series i.e. 2M + 2S and 2M + 4S) were omitted and space occupied by the soybean rows were left fellow. So two paired row of maize (row x row spacing, 60 cm) were planted at 90 cm distance in control₁ and 150 cm distance in control₂. 100% RDF was applied to both the control plots. The experimental data were statistically analyzed for analysis of variance and test of significance as described by Gomez and Gomez (1984).

Results and Discussion

Availability of nitrogen in soil

Availability of nitrogen in soil was significantly influenced by the treatments imposed. Observations were taken at periodic interval of 20 days till harvest i.e. at 20, 40, 60, 80 DAS and at harvest. Availability of the mineral nitrogen increase upto 60 DAS but after that till harvest decreasing trend was reported. This was due to the three reasons: (1) Side placement of fertilizer to the crops was done at the critical growth stages (between 40-60 DAS) of crop, application of fertilizer at this stage/duration has increased the availability of nutrients in soil (2) Maximum uptake of nutrients take place at major growth period of crop i.e. during 40-80 DAS and as the crop has already taken up the majority of nutrients from the soil during this time period, the availability of nutrient later on was decreased. (3) As the crop advances to harvesting, especially during 80 DAS to harvesting, the moisture level in the soil of the field goes down and this drastically reduces the availability of ammonium nitrogen. This is in agreement with Li et al., (2001).

Availability of ammonium-N

Among six crop arrangements, 2 maize + 4 soybean replacement series (C₄) showed the highest value of available NH₄⁺-N from 20 DAS till harvest except at 80 DAS when paired row replacement series (C₃) recorded the highest available NH₄⁺-N in soil (Table 1). However, these two treatments were reported at par at all the observational stages except at 60 DAS. This finding is in line with the result explained by Matusso et al., (2014).

On the other hand, comparatively lower availability NH₄⁺-N was observed from sole maize (C₁) and sole soybean (C₂). Further sole soybean (C₂) recorded the lowest value throughout the crop growth period. Higher availability of NH₄⁺-N in intercropping than sole planting is due to the contribution of biological nitrogen fixed by intercropped soybean in addition to the applied synthetic fertilizers. Among different nutrient management, treatments fertilized with 125% RDF (F₁) and 50% RDF (F₄) showed...
significantly higher and lower value of available NH$_4^+$-N, respectively, in soil over remaining nutrient managements. The reason behind this was increasing amount of nitrogen fertilizer application rates from 50% to 125% RDF. Kebeney et al., (2015) also reported the same.

**Availability of nitrate -N**

Throughout the crop growth stage highest availability of NO$_3^-$-N in soil was reported from C$_4$ i.e. 2 maize + 4 soybean intercropping system and this was found comparable with the additive series C$_5$ (Two rows of soybean added in between two rows of maize) at all the observational stage except at - harvest. Increase in NO$_3^-$-N content may be ascribed to nitrification of NH$_4^+$-N to NO$_3^-$-N by soil microorganisms (Santhy et al., 1998).

On the other hand, the lowest available NO$_3^-$-N in soil was recorded from sole soybean (C$_2$), however, this found comparable with sole maize throughout the crop growth period (Table 2). Regarding nutrient management maximum available NO$_3^-$-N in soil was obtained under highest amount of fertilizer applied soil i.e. 125% RDF. With the decrease in fertility levels from 125% RDF to 50% RDF significant decrease in NO$_3^-$-N availability in soil was reported.

**Mineral nitrogen (Ammonium and nitrate) supplemented by soybean to maize**

Legumes enrich soil by fixing the atmospheric nitrogen converting it from an inorganic form to forms that are available for plants uptake. Biological fixation of atmospheric nitrogen can replace nitrogen fertilization wholly or in part.

Biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems when nitrogen fertilizer is limited. Moreover, because inorganic fertilizers have much environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as a sustainable and alternative way of introducing N into lower input agro ecosystems (Fustec et al., 2010).

In Table 3 mean data related to the availability of NH$_4^+$-N (mg kg$^{-1}$ of soil) of the 24 treatment combinations of crop arrangements and nutrient managements (Rest) is presented which were compared to the two control treatments i.e. control$_1$ (Paired row maize planted at 60 cm and spacing between two pairs of rows was 90 cm + 100% RDF) and control$_2$ (Paired row maize were planted at 60 cm and spacing between two pairs was 150 cm + 100% RDF).

In case of availability of NH$_4^+$-N, non - significant difference between rest and controls were reported at 20 DAS, but later on mean availability of NH$_4^+$-N in soil of 24 treatments (Combinations of the crop arrangement and nutrient management) showed significant higher availability over both the controls (Table 3). Significant variation in the availability of NH$_4^+$-N in soil of control$_1$ and rest (Mean availability from 24 treatments) was recorded at all the observational stages.

But in case of control$_2$, the availability of NH$_4^+$-N was found comparable with rest upto 40 DAS of crop growth and afterward till harvest the mean availability from the 24 treatments i.e. rest was reported significantly superior over control$_2$. But the highest availability of NO$_3^-$-N in soil was reported from rest and this was followed by control$_2$ (two paired row of maize spaced at 60 cm planted at a distance of 150 cm with each other) throughout the crop growth stage (Table 4). Osunde et al., (2004) also found higher nitrogen availability in intercropping and observed that the proportion of nitrogen
derived from atmosphere fixation was about 40 percent in the intercropped soybean and 30 percent in the sole crop without the addition of fertilizer.

At harvest stage the 6.63 and 5.17 kg higher mean availability of NH$_4^+$-N ha$^{-1}$ was reported from the intercropping in comparison to control$_1$ and control$_2$, respectively and in case of NO$_3^-$-N this additional availability was 16.47 and 9.02 kg ha$^{-1}$ higher than control$_1$ and control$_2$, respectively.

Between the two controls, control$_2$ proved to be more advantageous over control$_1$ and showed higher availability of mineral nitrogen in soil, however the difference between the two controls was non-significant at all the observational stages.

### Grain yield

The grain yield was significantly influenced by different cropping system and nutrient levels. Among crop arrangements C$_3$, Maize + soybean (2:2, replacement series) produced significantly higher grain yield over rest of the crop arrangement (Table 5).

This was followed by additive series C$_5$ (two rows of soybean added in between two rows of maize). The significantly lower producer was sole soybean. Under maize + soybean intercropping systems, soybean yield tends to be lower and maize yield tends to be higher (Ghaffarzaeh et al., 1994). The increase in the total grain production of intercropping system obviously was the result of additional yield of soybean as bonus by utilization of inter-row space of maize crop.

### Table 1: Availability of NH$_4^+$-N in soil as influenced by the crop arrangement and nutrient management under maize + soybean intercropping system (Mean data of 2014 and 2015)

| Treatments | 20 DAS | 40 DAS | 60 DAS | 80 DAS | At harvest |
|------------|--------|--------|--------|--------|------------|
| **Crop arrangement** |        |        |        |        |            |
| C$_1$      | 16.61  | 31.66  | 44.43  | 34.44  | 26.71      |
| C$_2$      | 16.20  | 30.24  | 43.15  | 33.10  | 26.13      |
| C$_3$      | 17.45  | 33.13  | 46.07  | 37.18  | 28.09      |
| C$_4$      | 17.66  | 33.75  | 47.22  | 36.68  | 28.86      |
| C$_5$      | 17.20  | 32.54  | 45.52  | 35.72  | 27.55      |
| C$_6$      | 16.91  | 31.87  | 44.45  | 35.00  | 27.14      |
| **SEm±**   | 0.21   | 0.50   | 0.63   | 0.44   | 0.40       |
| **CD (P=0.05)** | 0.50   | 1.18   | 1.49   | 1.05   | 0.94       |
| **Nutrient management** |        |        |        |        |            |
| F$_1$      | 19.00  | 35.65  | 49.57  | 38.83  | 30.34      |
| F$_2$      | 17.33  | 32.93  | 46.43  | 35.97  | 28.32      |
| F$_3$      | 16.24  | 31.14  | 43.66  | 34.02  | 26.40      |
| F$_4$      | 15.43  | 29.07  | 40.89  | 32.59  | 24.58      |
| **SEm±**   | 0.17   | 0.40   | 0.51   | 0.36   | 0.32       |
| **CD (P=0.05)** | 0.41   | 0.96   | 1.22   | 0.86   | 0.77       |
Table 2 Availability of NO₃--N in soil as influenced by the crop arrangement and nutrient management under maize + soybean intercropping system (Mean data of 2014 and 2015)

| Treatments | 20 DAS | 40 DAS | 60 DAS | 80 DAS | At harvest |
|------------|--------|--------|--------|--------|-----------|
| **Crop arrangement** |        |        |        |        |           |
| C₁         | 53.50  | 66.26  | 92.48  | 73.00  | 55.04     |
| C₂         | 53.11  | 65.60  | 92.47  | 72.33  | 54.43     |
| C₃         | 56.13  | 68.54  | 95.40  | 75.31  | 56.24     |
| C₄         | 57.41  | 69.52  | 96.97  | 76.78  | 57.52     |
| C₅         | 55.25  | 67.87  | 94.28  | 74.49  | 55.97     |
| C₆         | 54.45  | 66.67  | 93.66  | 73.51  | 55.19     |
| **SEM±**   | 0.66   | 0.55   | 0.73   | 0.73   | 0.43      |
| **CD (P=0.05)** | 1.56  | 1.29   | 1.73   | 1.73   | 1.02      |
| **Nutrient management** |        |        |        |        |           |
| F₁         | 59.65  | 73.37  | 101.67 | 80.36  | 60.49     |
| F₂         | 56.20  | 68.66  | 96.66  | 76.22  | 56.85     |
| F₃         | 53.06  | 65.28  | 91.46  | 71.61  | 54.00     |
| F₄         | 51.00  | 62.34  | 87.05  | 68.75  | 51.58     |
| **SEM±**   | 0.54   | 0.45   | 0.59   | 0.59   | 0.35      |
| **CD (P=0.05)** | 1.27  | 1.06   | 1.41   | 1.41   | 0.83      |

C₁-sole maize, C₂-sole soybean, C₃-Maize+ soybean, 2:2, C₄-Maize+ soybean, 2:4, C₅-Two rows of soybean planted in between two rows of maize, C₆-One row of soybean planted in between two rows of maize, F₁-125% RDF, F₂-100% RDF, F₃-75% RDF, F₄-50% RDF

Table 3 Status of NH₄+ - N in the soil under maize + soybean intercropping system and control plots (Mean data of 2014 and 2015)

| Control vs. rest | 20 DAS | 40 DAS | 60 DAS | 80 DAS | At harvest |
|------------------|--------|--------|--------|--------|------------|
| **Rest**         | 17.00  | 32.20  | 45.14  | 35.35  | 27.41      |
| **Control₁**     | 16.53  | 28.95  | 41.40  | 32.03  | 24.46      |
| **SEM±**         | 0.43   | 1.01   | 1.28   | 0.91   | 0.82       |
| **SED±**         | 0.60   | 1.40   | 1.78   | 1.25   | 1.14       |
| **CD (P=0.05)**  | NS     | 2.82   | 3.57   | 2.52   | 2.28       |
| **Control₂**     | 17.29  | 31.11  | 41.67  | 32.56  | 25.11      |
| **SEM±**         | 0.43   | 1.30   | 1.30   | 0.90   | 0.81       |
| **SED±**         | 0.59   | 1.42   | 1.25   | 1.25   | 1.12       |
| **CD (P=0.05)**  | NS     | 2.87   | 3.61   | 2.50   | 2.25       |
| **Con₁ vs. Con₂**| NS     | NS     | NS     | NS     | NS         |
### Table 4
Status of NO$_3$-N in soil under maize + soybean intercropping system and control plots (Mean data of 2014 and 2015)

| Control vs. rest | Available nitrate-N (mg kg$^{-1}$ of soil) | 20 DAS | 40 DAS | 60 DAS | 80 DAS | At harvest |
|------------------|----------------------------------------|--------|--------|--------|--------|------------|
| Rest             |                                       |        |        |        |        |            |
| Control$_1$      |                                       | 49.96  | 55.64  | 81.12  | 60.37  | 48.41      |
| SEm±             |                                       | 1.34   | 1.11   | 1.48   | 1.50   | 0.87       |
| SEd+             |                                       | 1.86   | 1.54   | 2.05   | 2.06   | 1.21       |
| CD (P=0.05)      |                                       | 3.74   | 3.10   | 4.13   | 4.14   | 2.43       |
| Control$_2$      |                                       | 51.16  | 59.95  | 89.48  | 60.69  | 51.72      |
| SEm±             |                                       | 1.12   | 0.87   | 1.49   | 1.38   | 0.94       |
| SEd+             |                                       | 1.55   | 1.21   | 2.06   | 1.91   | 1.30       |
| CD (P=0.05)      |                                       | 3.12   | 2.43   | 4.14   | 3.84   | 2.61       |
| Con$_1$ vs. Con$_2$ |                                   | NS     | NS     | NS     | NS     | NS         |

Rest- Mean availability of NH$_4^+$ - N in soil from 24 combination of crop arrangement and nutrient management, Control$_1$ - Paired row planting of maize at 60 cm and spacing between two pairs was 90 cm + 100% RDF, Control$_2$ - Paired row planting of maize at 60 cm and spacing between two pairs was 150 cm + 100% RDF.

### Table 5
Effect of cropping arrangement and fertility levels on light interception (%) and grain maize equivalent yield (q ha$^{-1}$) of maize under maize + soybean intercropping system (Mean data of 2014 and 2015)

| Treatment                                      | Grain maize equivalent yield (q ha$^{-1}$) |
|------------------------------------------------|-------------------------------------------|
| Cropping arrangement                           |                                           |
| C$_1$ (Sole maize)                             | 60.30                                     |
| C$_2$ (Sole soybean)                           | 27.80                                     |
| C$_3$ (Maize + soybean, 2:2)                   | 71.90                                     |
| C$_4$ (Maize + Soybean, 2:4)                   | 49.00                                     |
| C$_5$ (Two row of soybean planted in between two row of maize) | 64.60                                     |
| C$_6$ (One row of soybean planted in between two row of maize) | 63.20                                     |
| SEm±                                           | 0.84                                      |
| CD (P=0.05)                                    | 2.36                                      |
| Nutrient management                            |                                           |
| F$_1$(125% RDF)                                | 62.50                                     |
| F$_2$(100% RDF)                                | 59.10                                     |
| F$_3$(75% RDF)                                 | 53.70                                     |
| F$_4$(50% RDF)                                 | 49.20                                     |
| SEm±                                           | 0.69                                      |
| CD (P=0.05)                                    | 1.93                                      |
Htet et al., (2016) indicated that, legume contribution to corn in mixtures was significant and increased the total biomass yield of mixtures. Our findings are in accordance with these researches. Among four nutrient levels, the grain yield obtained from F	extsubscript{1} (125% RDF) was highest and significantly superior because of the superior yield attributing characters. Panhwar et al., (2004) concluded that fertilizer levels exhibited highly significant effect on grain yield of maize. However, the lowest grain yield was reported from the treatment with 50% RDF (F	extsubscript{4}).

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