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**Vinay Bachkaiya**
Department of Soil Science and Agricultural Chemistry, CoA, Raipur, Chhattisgarh, India

**Amina Anisha Ekka**
Department of Soil Science and Agricultural Chemistry, CoA, Raipur, Chhattisgarh, India

**Biplab Choudhari**
Department of Soil Science and Agricultural Chemistry, CoA, Raipur, Chhattisgarh, India

**Anshita Bajpa**
Department of Agronomy, CoA, Raipur, Chhattisgarh, India

**RK Bajpai**
Department of Soil Science and Agricultural Chemistry, CoA, Raipur, Chhattisgarh, India

**K Tedia**
Department of Soil Science and Agricultural Chemistry, CoA, Raipur, Chhattisgarh, India

**Corresponding Author:**
**Vinay Bachkaiya**
Department of Soil Science and Agricultural Chemistry, CoA, Raipur, Chhattisgarh, India

# Evaluation of fly-ash application on yield and nutrient uptake by soybean-chickpea in a Vertisol of Chhattisgarh

**Vinay Bachkaiya, Amina Anisha Ekka, Biplab Choudhari, Anshita Bajpa, RK Bajpai and K Tedia**

**Abstract**
The field inquiry was carried out with a soybean-chickpea cropping sequence at the instructional cum research farm of Indira Gandhi Krishi Vishwavidyalaya Raipur (Chhattisgarh) during the Kharif and Rabi seasons in 2019–2020 and 2020–21, respectively. In a Vertisol, the yield of soybean and chickpea as well as the primary nutrient uptake were investigated. The experiment used a randomized block design (RBD) with twelve treatments that were repeated three times. Over the control plot, the addition of 100% RDF + 40 t/ha Fly ash increased soybean and chickpea yields as well as primary nutrient uptake.

**Keywords:** Fly ash, soybean, chickpea, yield, nutrient uptake

## Introduction
Thermal power plants burn coal, which results in the production of fly ash, which is then released into ash ponds. As a by product of pulverized coal-fired thermal power plants, fly ash is an amorphous ferroalumino silicate with tiny particles (60–70%) that are less than 0.075 mm in size and low to medium bulk density, large surface area, and very light texture (Lal *et al.*, 2014) [5]. More than 100 million tonnes of FA are produced annually by thermal power plants in India; this number is predicted to rise to 175 million in the near future. India currently produces up to 500 MT of fly ash per year (Kumar and Pandey, 2022) [7].
Chhattisgarh is major fly-ash generating state in India, because of it's large quantity of coal reserves as there are 15 major thermal power plant. The state generates large amount of over 20 million tonnes fly ash in thermal power plants with a meagre utilization of 6-8 million tonnes a year.
FA use in agriculture offers a workable option for its secure disposal to promote crop productivity and the soil environment. The MoEFCC has updated the guidelines for using fly ash and mandated that farmers within a 300-kilometer radius receive fly ash free of charge. FA use in agriculture may offer a workable solution for its secure disposal without significant negative impacts. However, FA's physical and chemical makeup varied greatly; as a result, the way it is used in agriculture varies and is dependent on the features of the soil or kind of soil. The growth and production of crops, as well as the physical and chemical qualities of the soil, were all altered by the application of FA to the soil.
With an area of 5.9 Mha and 7.6 Mha, respectively, soybean and chickpea are the two most important oilseed and pulse crops in India. 10.68 q/ha of soybeans are produced, compared to 12.17 q/ha of chickpeas. In Chhattisgarh, soybeans are planted on an area of 71.07 t ha, producing 7.31 q/ha on average, while chickpeas are produced on an area of 363.16 t ha, producing 9.32 q/ha on average (2020–2021). As with fertilizers and other agricultural inputs, the kind of soil, the crop to be produced, the current agro-climatic situation, as well as the type of fly ash available, will all influence how much, when, and how to apply fly ash. The purpose of this experiment was to determine the impact of either fly ash or FYM

## Materials and Methods
The current study was carried out with soy and chickpea crops in a Vertisol at the Instructional Cum Research Farm, IGKV, Raipur, (Chhattisgarh) in the Kharif and Rabi seasons of 2019–20 and 2020–21, respectively. The experimental site is 293 meters above mean sea level and is situated between latitudes 20° 4" North and 81° 39" East.

The area experiences a subhumid environment. The average annual rainfall of Raipur is between 1200 and 1400 mm, with 88% of the total falling between June and September and 8% between October and February. Raipur has a dry, moist, subtropical climate. The hottest month of the year is May, while the coolest is December. The rainfall pattern has great variations during rainy season from year to year. The temperature during the summer months reaches as high as 48°C and drop to 6°C during December to January.

The experimental soil was a medium black clay texture with a pH of 7.62, electrical conductivity (EC) of 0.21 $dSm^{-1}$ (1:2.5: soil: water ratio), and soil organic carbon of 5.8 g kg-1. It is a member of the Aarang-II series of fine Montmorillonitic hyperthermic family of Typic chromustert (Vertisol). There were 210, 18.23, and 491 kg $ha^{-1}$ of nitrogen (N), phosphorus (P), and potassium (K) readily available, respectively. There are 12 treatments total in the experiment: T1: Control, 50% RDF in T2, 100% RDF in T3, 20 t/ha fly ash in T4, and 40 t/ha fly ash in T5. 5 t/ha FYM in T6, 50% RDF plus 20 t/ha fly ash in T7, 50% RDF plus 40 t/ha fly ash in T8, and 100% RDF plus 20 t/ha fly ash in T9. T10: 40 t/ha of fly ash and 100% RDF T12: 20 t/ha fly ash plus 5 t/ha FYM in T11.

As test crops, the soybean cultivar CG soya-1 and the chickpea cultivar Vaibhav were cultivated with the suggested fertilizer application (20:60:40 kg $ha^{-1}$ N:P2O5:K2O). Soybean seeds were sown 40 cm apart by 10 cm apart, whereas chickpea seeds were sown 40 cm apart by 20 cm apart. Urea, single super phosphate (SSP), and muriate of potash (MOP), respectively, were used to apply N, P, and K nutrients. At the time of seeding, a third (1/3) of the authorized dose of urea and P and K were administered. According to the treatment specifics, FYM and fly ash were administered as the field was being prepared. Soybean and chickpea seeds were individually gathered at full maturity from the net plot and the border field. By dissolving a 0.5 gram sample in acid ($H_2SO_4$) and analyzing the results using a conventional titration approach, the nitrogen content of the plant was ascertained. One gram of oven-dried plant sample was digested with 10 ml of an acid mixture ($HNO_3$ and HCl in a 9:4 ratio) to measure the amount of phosphorus and potassium present in the plant (seed and haulm), and the final volume was created using 100 ml of deionized water. Spectrophotometry and flame photometry were used to measure the total concentration of P and K (Piper, 1966). By multiplying nutrient content and grain and straw production, the uptake of key nutrients by soybean and chickpea was calculated.

## Results and Discussion

### Soybean yield

By dissolving a 0.5 gram sample in acid ($H_2SO_4$) and analyzing the results using a conventional titration approach, the nitrogen content of the plant was ascertained. One gram of oven-dried plant sample was digested with 10 ml of an acid mixture ($HNO_3$ and HCl in a 9:4 ratio) to measure the amount of phosphorus and potassium present in the plant (seed and haulm), and the final volume was created using 100 ml of deionized water. Spectrophotometry and flame photometry were used to measure the total concentration of P and K (Piper, 1966). By multiplying nutrient content and grain and straw production, the uptake of key nutrients by soybean and chickpea was calculated. The seed yield of soybean followed almost similar trend in 2020 with highest yield was recorded under 100% RDF + 40 t $ha^{-1}$ (25.14 q $ha^{-1}$) and found significantly higher than yield recorded under 50% RDF (19.46 q $ha^{-1}$), 20 t $ha^{-1}$ FA (13.05 q $ha^{-1}$), 40 t $ha^{-1}$ FA (13.19 q $ha^{-1}$), 5 t $ha^{-1}$ FYM (16.38 q $ha^{-1}$) 50% RDF + 20 t $ha^{-1}$ FA (19.21 q $ha^{-1}$), 50% RDF + 40 t $ha^{-1}$ FA (19.97 q $ha^{-1}$), 5 t $ha^{-1}$ FYM + 20 t $ha^{-1}$ FA (15.06 q $ha^{-1}$) and 5 t $ha^{-1}$ FYM + 40 t $ha^{-1}$ FA (15.71q $ha^{-1}$). The seed yield of soybean exhibited at par results in 100% RDF + 40 t $ha^{-1}$ FA, 100% RDF and 100% RDF + 20 t $ha^{-1}$ FA.

Both cropping seasons (2019 & 2020) saw a comparable haulm yield. However, in 2019 and 2020, the maximum haulm yield of soybean (36.19 q $ha^{-1}$ and 36.6 q $ha^{-1}$, respectively) was achieved with 100% RDF + 20 t $ha^{-1}$ FA. However, in 2019 and 2020, the haulm yield under 100% RDF + 20 t $ha^{-1}$ was comparable to that under 100% RDF + 40 t ha-[1] FA (35.42 q $ha^{-1}$ and 35.58 q $ha^{-1}$), 100% RDF (32.89 q $ha^{-1}$ and 33.10 q $ha^{-1}$) and 50% RDF + 40 t $ha^{-1}$ FA (32.20 q $ha^{-1}$ and 32.49 q $ha^{-1}$). The haulm yield of soybean was shown to be unaffected by the sole application of fly ash, similar to grain yield, as shown by the control's at par yield (26.39 q $ha^{-1}$). Due to the fly ash's low levels of phosphorus, potassium, manganese, and zinc as well as its low levels of organic carbon and nitrogen, the integration of fly ash alone did not appreciably change the seed or haulm yield. Fly ash has a limited nutrient content, which was not enough to impact the yield when used alone. However, the addition of fly ash to RDF greatly increased the yield of soybean in Vertisol. This improvement in yield may have been caused by enhanced physical conditions for crop growth and nutrient delivery from the applied fertilizer. The results of the current study are consistent with those of earlier studies published by Gaind and Gaur (2002) [3], Mittra *et al* (2005) [6], Bhople *et al* (2011) [1], and Singh *et al* (201)

### Chickpea yield

The data shown in Table 2 and graphically represented in Figures 1 and 2 indicated the effect of applying fly ash alone or in combination with RDF and FYM on the seed and haulm yield of chickpea. According to the statistics, neither the 2019–0 cropping season nor the 2020–21 cropping season's seed or harvest yield of chickpea was impacted by the application of fly ash alone. The application of 100% RDF + 40 t $ha^{-1}$ resulted in the highest seed yield in 2019–20 (21.14 q $ha^{-1}$), which was significantly higher than the seed yields of 50% RDF (16.41 q $ha^{-1}$), 20 t $ha^{-1}$ FA (11.73 q $ha^{-1}$), 40 t $ha^{-1}$ FA (12.37 q $ha^{-1}$), 5 t $ha^{-1}$ FYM (13.92 q ha–1).

**Table 1:** Effect of fly ash application on seed and haulm yield (q $ha^{-1}$) of soybean

| Treatments | Seed Yield | | | Haulm Yield | | |
|---|---|---|---|---|---|---|
| | Soybean 2019 | Soybean 2020 | Mean | Soybean 2019 | Soybean 2020 | Mean |
| T1:Control | $12.33^{d}$ | $13.38^{d}$ | $12.85^{d}$ | $26.39^{cd}$ | $26.74^{cd}$ | $26.56^{cd}$ |
| T2:50% RDF | $18.04^{bc}$ | $19.46^{bc}$ | $18.75^{b}$ | $30.71^{bc}$ | $31.00^{bc}$ | $30.86^{bc}$ |
| T3:100% RDF | $24.80^{a}$ | $24.55^{a}$ | $24.68^{a}$ | $32.89^{ab}$ | $33.10^{ab}$ | $32.99^{ab}$ |
| T4:20 t/ha FA | $13.04^{d}$ | $13.05^{d}$ | $13.04^{d}$ | $24.72^{d}$ | $24.52^{d}$ | $24.62^{d}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| T5:40 t/ha FA | 13.96[d] | 13.19[d] | 13.58[d] | 24.27[d] | 24.57[d] | 24.42[d] |
| T6:5 t/ha FYM | 15.90[cd] | 16.38[cd] | 16.14[c] | 25.10[d] | 25.49[d] | 25.30[d] |
| T7:50% RDF + 20 t/ha FA | 19.99[b] | 19.21[bc] | 19.60[b] | 26.55[cd] | 26.24[cd] | 26.39[cd] |
| T8:50% RDF + 40 t/ha FA | 20.06[b] | 19.97[b] | 20.01[b] | 32.20[ab] | 32.49[ab] | 32.35[ab] |
| T9:100% RDF + 20 t/ha FA | 24.23[a] | 24.58[a] | 24.40[a] | 36.19[a] | 36.61[a] | 36.40[a] |
| T10:100% RDF + 40 t/ha FA | 24.95[a] | 25.14[a] | 25.04[a] | 35.42[ab] | 35.58[ab] | 35.50[ab] |
| T11:5 t/ha FYM + 20 t/ha FA | 15.69[cd] | 15.06[cd] | 15.37[cd] | 25.01[d] | 25.29[d] | 25.15[d] |
| T12:5 t/ha FYM + 40 t/ha FA | 15.93[cd] | 15.71[cd] | 15.82[cd] | 25.93[d] | 25.90[d] | 25.91[d] |
| SE m (±) | 1.07 | 1.34 | 0.81 | 1.56 | 1.59 | 1.57 |
| CD (p = 0.05) | 3.15 | 3.94 | 2.38 | 4.57 | 4.66 | 4.60 |

The control group's seed output was the lowest (11.40 q ha$^{-1}$). The yield under 100% RDF + 40 t ha$^{-1}$ FA, on the other hand, was comparable to that of 100% RDF, 100% RDF + 20 t ha$^{-1}$ FA, 50% RDF + 20 t ha$^{-1}$ FA, 50% RDF + 40 t ha$^{-1}$ FA, and 50% RDF + 40 t ha$^{-1}$ FA. The seed yields under 50% RDF, 50% RDF + 20 t ha$^{-1}$ FA, and 50% RDF + 40 t ha$^{-1}$ FA were all comparable. Application of 20 t ha$^{-1}$ FA and 40 t ha$^{-1}$ FA with 5 t ha$^{-1}$ FYM registered at par seed yield (14.21 q ha$^{-1}$ and 15.06 q ha$^{-1}$, respectively) with 50% RDF (16.41 q ha$^{-1}$).

With the highest yield recorded under 100% RDF + 40 t ha$^{-1}$ (21.63 q ha$^{-1}$), significantly higher than yields recorded under 50% RDF (15.38 q ha$^{-1}$), 20 t ha$^{-1}$ FA (11.34 q ha$^{-1}$), 40 t ha$^{-1}$ FA (12.03 q ha$^{-1}$), and 5 t ha$^{-1}$ FYM (14.70 q ha$^{-1}$), the seed yield of chickpeas in 2020–21 followed a trend that was almost identical to that in 2019– 50% RDF + 20 t ha$^{-1}$ FA, 50% RDF + 40 t ha$^{-1}$ FA, 5 t ha$^{-1}$ FYM + 20 t ha$^{-1}$ FA, and 5 t ha$^{-1}$ FYM + 40 t ha$^{-1}$ FA all resulted in 15.06 q ha$^{-1}$, 13.70 q ha$^{-1}$, and 13.13 q ha$^{-1}$, respectively. Chickpea seed production at par yields 100% RDF + 40 t ha$^{-1}$ FA, 100% RDF, and 100% RDF + 20 t ha$^{-1}$ FA.

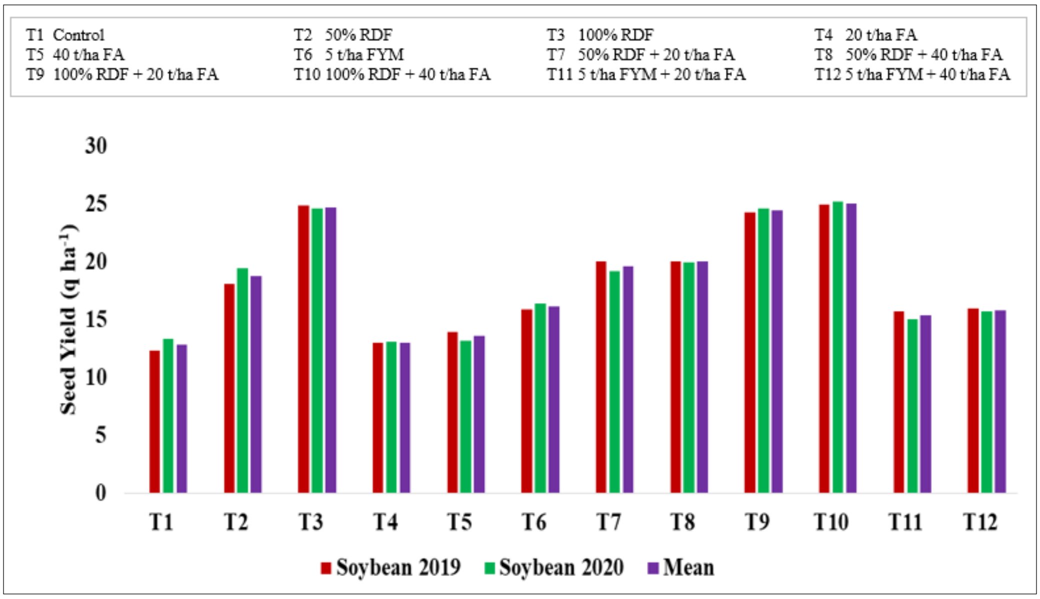


**Fig 1:** Effect of fly ash application on seed yield (q ha$^{-1}$) of soybean

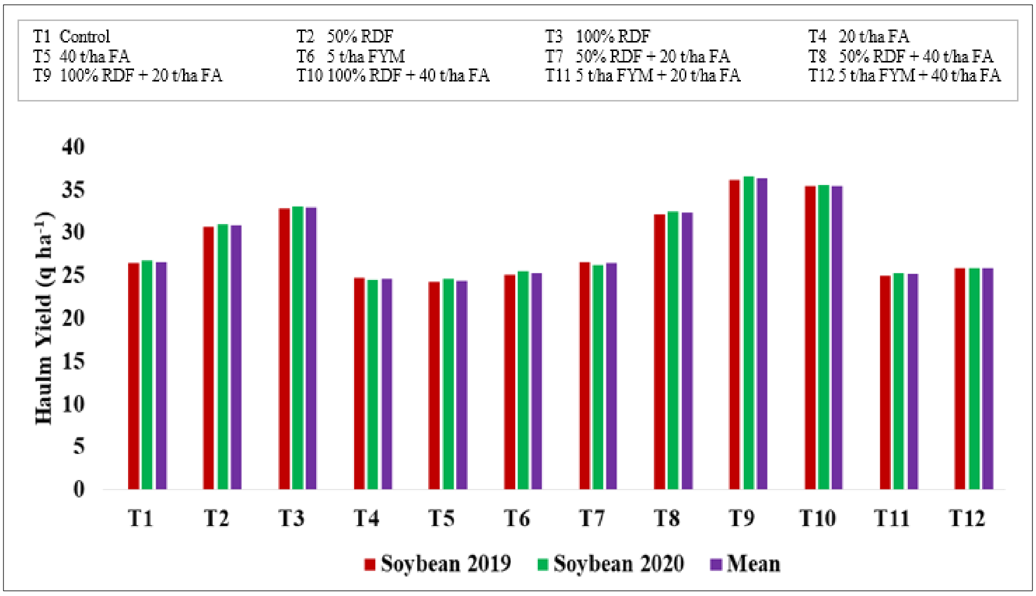


**Fig 2:** Effect of fly ash application on haulm yield (q ha$^{-1}$) of soybean

The chickpea harvest yield in both the cropping seasons (2019–20 & 2020–21) followed a similar pattern. Under 100% RDF + 40 t ha$^{-1}$ FA, the maximum chickpea haulm yield was attained in 2019–20 and 2020–21 (38.90 q ha$^{-1}$ and 34.90 q ha$^{-1}$, respectively). The haulm yield under 100% RDF + 40 t ha$^{-1}$, however, was comparable to that under 100% RDF + 20 t ha$^{-1}$ FA (36.61 q ha$^{-1}$ and 34.15 q ha$^{-1}$) and 100% RDF (36.10 q ha$^{-1}$ and 32.77 q ha$^{-1}$) in 2019–20 and 2020–21, respectively. Fly ash application alone was not found to be helpful in increasing chickpea haulm yield, similar to grain yield, as shown by at par yield in control (22.40 q ha$^{-1}$), 20 t ha$^{-1}$ FA (23.86 q ha$^{-1}$ and 22.86 q ha$^{-1}$).Not increasing the seed and harvest yield of chickpea under sole application of fly ash may be due to the low nutrient content with respect to phosphorus, potassium, and very little nitrogen and organic carbon along with low manganese, copper, and zinc. Fly ash has a limited nutrient content, which was not enough to impact the yield when used alone. However, the addition of fly ash to RDF greatly increased the yield of chickpea in Vertisol. This improvement in yield may have been caused by enhanced physical conditions for crop growth and nutrient availability from the applied fertilizer. The current study's findings are consistent with those of earlier studies published by Rautaray *et al*. (2003) [8], Deepa and Poonkodi (2004) [2], Mittra *et al*. (2005) [6], and Bhople *et al* (2011) [1].

**Table 2:** Effect of fly ash application on seed and haulm yield (q ha$^{-1}$) of chickpea

| Treatments | Seed Yield | | | Haulm Yield | | |
|---|---|---|---|---|---|---|
| | Chickpea 2019-20 | Chickpea 2020-21 | Mean | Chickpea 2019-20 | Chickpea 2020-21 | Mean |
| T1:Control | 11.40$^{e}$ | 12.56$^{bcd}$ | 11.98$^{bcd}$ | 22.40$^{c}$ | 22.40$^{d}$ | 12.40$^{d}$ |
| T2:50% RDF | 16.41$^{bcd}$ | 15.38$^{bc}$ | 15.89$^{bc}$ | 34.01$^{ab}$ | 24.02$^{cd}$ | 29.02$^{cd}$ |
| T3:100% RDF | 20.91$^{a}$ | 21.30$^{a}$ | 21.11$^{a}$ | 36.10$^{a}$ | 32.77$^{ab}$ | 34.43$^{ab}$ |
| T4:20 t/ha FA | 11.73$^{e}$ | 11.34$^{d}$ | 11.54$^{d}$ | 23.86$^{c}$ | 22.86$^{cd}$ | 23.36$^{cd}$ |
| T5:40 t/ha FA | 12.37$^{e}$ | 12.03$^{cd}$ | 12.20$^{cd}$ | 25.57$^{c}$ | 25.57$^{cd}$ | 25.57$^{cd}$ |
| T6:5 t/ha FYM | 13.92$^{de}$ | 14.70$^{bcd}$ | 14.31$^{bcd}$ | 25.49$^{c}$ | 25.49$^{cd}$ | 25.49$^{cd}$ |
| T7:50% RDF + 20 t/ha FA | 17.71$^{abc}$ | 15.06$^{bc}$ | 16.39$^{bc}$ | 38.90$^{a}$ | 27.24$^{bcd}$ | 33.07$^{bcd}$ |
| T8:50% RDF + 40 t/ha FA | 18.05$^{ab}$ | 15.67$^{b}$ | 16.86$^{b}$ | 28.83$^{bc}$ | 28.83$^{abc}$ | 28.83$^{abc}$ |
| T9:100% RDF + 20 t/ha FA | 21.03$^{a}$ | 20.07$^{a}$ | 20.55$^{a}$ | 36.61$^{a}$ | 34.15$^{a}$ | 35.38$^{a}$ |
| T10:100% RDF + 40 t/ha FA | 21.14$^{a}$ | 21.63$^{a}$ | 21.38$^{a}$ | 38.90$^{a}$ | 34.90$^{a}$ | 36.90$^{a}$ |
| T11:5 t/ha FYM + 20 t/ha FA | 14.21$^{cde}$ | 13.70$^{bcd}$ | 13.96$^{bcd}$ | 24.93$^{c}$ | 21.60$^{d}$ | 23.27$^{d}$ |
| T12:5 t/ha FYM + 40 t/ha FA | 15.06$^{bcde}$ | 13.13$^{bcd}$ | 14.09$^{bcd}$ | 26.54$^{c}$ | 25.57$^{cd}$ | 26.06$^{cd}$ |
| SE m (±) | 1.13 | 1.01 | 0.74 | 2.08 | 1.92 | 1.65 |
| CD (p = 0.05) | 3.31 | 2.98 | 2.17 | 6.10 | 6.12 | 4.83 |

**Effect of fly ash application on uptake of primary nutrients by soybean and chickpea**

To determine the impact of applying fly ash alone or in combination with other fertilizers on the uptake of nutrients by soybean and chickpea, the contents of the primary nutrients (N, P, and K) were analyzed and uptake was computed. The acquired results are displayed or discussed further down.

**Nitrogen uptake**

Table 3's data on nitrogen uptake as influenced by fly ash application alone versus fly ash application combined with RDF and FYM showed that fly ash application alone had no appreciable impact on nitrogen uptake by soybean and chickpea during either the 2019–20 or 2020–21 growing seasons. However, when FA and RDF were applied together, the nitrogen absorption was noticeably higher.

The soybean's 2019 nitrogen uptake was highest with 100% RDF + 40 t ha$^{-1}$ FA and lowest under control (108.70 kg ha$^{-1}$). The nitrogen uptake was found to be significantly higher with 100% RDF + 40 t ha$^{-1}$ FA (246.59 kg ha$^{-1}$) than 50% RDF (167.26 kg ha$^{-1}$), 20 t ha$^{-1}$ FA (127.34 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (114.25 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (152.79 kg ha$^{-1}$), 50% RDF + 20 t ha$^{-1}$ FA (181.41 kg ha$^{-1}$), 50% RDF + 40 t ha$^{-1}$ FA (189.69 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM + 20 t ha$^{-1}$ FA (141.49 kg ha$^{-1}$) and 5 t ha$^{-1}$ FYM + 40 t ha$^{-1}$ FA (145.83 kg ha$^{-1}$). However, soybean nitrogen uptake in 2019 was found to be comparable.

Similar patterns in nitrogen uptake were seen in soybean (2020), however 100% RDF (173.42 kg ha$^{-1}$) considerably outperformed 100% RDF + 40 t ha$^{-1}$ FA (157.64 kg ha$^{-1}$) and 100% RDF + 20 t ha$^{-1}$ FA (168.52 kg ha$^{-1}$) in terms of nitrogen uptake. Control had the lowest nitrogen uptake (98.97 kg ha$^{-1}$)The nitrogen uptake by chickpea (in 2019–20 and 2020–21, respectively) shows that 100% RDF + 20 t ha$^{-1}$ FA (152.19 kg ha$^{-1}$ and 184.78 kg ha$^{-1}$) results in the highest nitrogen uptake, while 100% RDF (148.90 kg ha$^{-1}$ and 193.07 kg ha$^{-1}$) and 100% RDF + 40 t ha–1 FA (133.23 kg ha$^{-1}$ and 211.34 kg ha$^{-1}$) are at parity.

In 2019–20, 100% RDF + 20 t ha$^{-1}$ FA produced the highest nitrogen uptake by chickpea (152.19 kg ha$^{-1}$) and the lowest (76.25 kg ha$^{-1}$) results. The nitrogen uptake was found to be significantly higher with 100% RDF + 20 t ha$^{-1}$ FA (152.19 kg ha$^{-1}$) than 50% RDF (121.23 kg ha$^{-1}$), 20 t ha-1 FA (93.84 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (94.22 kg ha$^{-1}$), 5 t ha-1 FYM (92.26 kg ha$^{-1}$), 50% RDF + 40 t ha$^{-1}$ FA (120.98 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM + 20 t ha$^{-1}$ FA (90.80 kg ha$^{-1}$) and 5 t ha$^{-1}$ FYM + 40 t ha$^{-1}$ FA (98.81 kg ha$^{-1}$).

Similar patterns in nitrogen uptake were seen in chickpea (2020–21), however 100% RDF + 40 t ha$^{-1}$ FA (211.34 kg ha$^{-1}$) considerably outperformed 100% RDF + 20 t ha$^{-1}$ FA (184.78 kg ha$^{-1}$) and 100% RDF (193.07 kg ha$^{-1}$) in terms of nitrogen uptake. The control (99 kg ha$^{-1}$) had the lowest nitrogen uptake.

The enhanced yield seen under these treatments may be ascribed to the increased nitrogen absorption brought on by the application of RDF together with FA. Rajkumar (2000) [7], Hussain Saheb (1993) [4], and Singh & Singh (1986) [10] all reported observations of a similar nature.

**Phosphorus uptake**

Table 4 presents the results on phosphorus uptake as modified by the application of fly ash, either alone or in conjunction with RDF and FYM. The findings showed that alone applying fly ash had no discernible impact on how much phosphorus

soybean and chickpea absorbed during the two years (2019–20 & 2020–21). However, when FA and RDF were applied together, phosphorus uptake was noticeably higher.
In soybean (2019), 100% RDF + 20 t ha$^{-1}$ FA resulted in the maximum phosphorus uptake (19.73 kg ha$^{-1}$) and the lowest (9.55 kg ha$^{-1}$) levels. The amount of phosphorus absorbed was found to be significantly higher with 100% RDF + 20 t ha$^{-1}$ FA (19.73 kg ha$^{-1}$) than with 50% RDF (13.68 kg ha$^{-1}$), 20 t ha-1 FA (10.31 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (10.62 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (11.74 kg ha$^{-1}$), and 50% RDF + 20 t ha$^{-1}$ FA (14.76 kg ha$^{-1}$). While soybean's 2019 phosphorus uptake was determined to be at parity with 100% RDF (17.71 kg ha$^{-1}$), 100% RDF + 20
Similar results were seen in soybean (2020) with regard to phosphorus uptake, however 100% RDF + 40 t ha$^{-1}$ FA (20.72 kg ha$^{-1}$) reported significantly higher phosphorus uptake, matching that of 100% RDF + 20 t ha$^{-1}$ FA (20.38 kg ha$^{-1}$) and 100% RDF (17.68 kg ha$^{-1}$). The control group (12.49 kg ha$^{-1}$) had the lowest phosphorus intake.
The phosphorus uptake by chickpea (2019–20 and 2020–21, respectively) shows that 100% RDF + 40 t ha$^{-1}$ FA (11.18 kg ha$^{-1}$ and 12.18 kg ha$^{-1}$) and 100% RDF–20 t ha$^{-1}$ FA (11.93 kg ha$^{-1}$ and 12.66 kg ha$^{-1}$) are the two treatments that result in the highest phosphorus uptake.
In 2019–20, 100% RDF + 40 t ha$^{-1}$ FA produced the highest chickpea phosphorus uptake (12.15 kg ha$^{-1}$) and the lowest (5.69 kg ha$^{-1}$) results. The phosphorus uptake was shown to be considerably higher with 100% RDF + 40 t ha$^{-1}$ FA than with 50% RDF (8.74 kg ha$^{-1}$), 20 t ha$^{-1}$ FA (7.54 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (7.01 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (6.33 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM + 20 t ha$^{-1}$ FA (5.61 kg ha$^{-1}$), and 5 t ha$^{-1}$ FYM + 40 t ha$^{-1}$ FA.
Similar trends in phosphorus uptake were seen in chickpea (2020–2021), but 100% RDF + 40 t ha$^{-1}$ FA (12.95 kg ha$^{-1}$) was significantly higher than 50% RDF (7.93 kg ha$^{-1}$), 20% FA (5.99 kg ha$^{-1}$), 40% FA (6.56 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (7.25 kg ha$^{-1}$), and 20% FYM + 40 t ha$^{-1}$ FA (6.47 kg ha$^{-1}$) and significantly higher than 100% RDF (12.66 kg ha$^{-1}$). The least amount of phosphorus was absorbed in the control group (6.0 kg ha$^{-1}$).
The enhanced yield seen under these treatments may be related to the increased phosphorus uptake brought on by the application of RDF together with FA. Singh and Singh (1986) [10], Hussain Saheb (1993) [4], and Rajkumar (2000) [7] all reported on related findings.

**Potassium uptake**
Table 5 shows the impact of applying fly ash alone or in combination with RDF and FYM on the uptake of potassium by soybean and chickpea. The information showed that the administration of FA and RDF separately had no significant effect on potassium uptake by soybean and chickpea during either of the two years (2019–20 or 2020–21).
The highest potassium uptake by soybean was found to be under 100% RDF + 40 t ha$^{-1}$ FA (120.46 kg ha$^{-1}$) in 2019 and was found to be significantly higher than 50% RDF (103.37 kg ha-1), 20 t ha$^{-1}$ FA (78.24 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (75.60 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (87.05 kg ha$^{-1}$), 50% RDF + 20 t ha$^{-1}$ FA (102.32 kg ha$^{-1}$), and 78.55 kg ha$^{-1}$ for 5 t ha$^{-1}$ FYM plus 20 t ha$^{-1}$ FA and 80.04 kg ha$^{-1}$ for 5 t ha$^{-1}$ FYM plus 40 t ha$^{-1}$ FA. Under 100% RDF (112.81 kg ha$^{-1}$), 100% RDF + 20 t ha$^{-1}$ FA (129.39 kg ha$^{-1}$) and 100% RDF + 40 t ha$^{-1}$ FA, the potassium absorption by soybean (2019) was found to be equivalent.
In terms of potassium uptake, soybeans (2020) followed a nearly identical trajectory. The highest potassium uptake was observed under 100% RDF + 40 t ha$^{-1}$ FA (123.77 kg ha$^{-1}$), which was significantly higher than 50% RDF (94.58 kg ha$^{-1}$), 20 t ha$^{-1}$FA (79.84 kg ha$^{-1}$), 40 t ha$^{-1}$FA (74.47 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (85.60 kg ha$^{-1}$), 50% RDF + 20 t ha$^{-1}$ FA (89.26 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM + 20 t FA.
The highest potassium uptake by chickpeas was found to be with 100% RDF + 40 t h ha$^{-1}$ FA (127.62 kg ha-1), which was found to be significantly higher than 50% RDF (97.31 kg ha$^{-1}$), 20 t ha$^{-1}$ FA (78.46 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (79.50 kg ha$^{-1}$), 5 t ha-1 FYM (80.64 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM + 20 t ha$^{-1}$ FA.
The percentage of potassium that chickpeas absorbed varied from control (60.88 kg ha$^{-1}$) to 100% RDF + 40 t ha$^{-1}$ FA (104.11 kg ha$^{-1}$). The potassium uptake was found to be significantly higher with 100% RDF + 40 t ha$^{-1}$ FA than 50% RDF (77.89 kg ha$^{-1}$), 20 t ha$^{-1}$ FA (64.88 kg ha$^{-1}$), 40 t ha$^{-1}$ FA (68.00 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM (77.41 kg ha$^{-1}$), 50% RDF + 20 t ha$^{-1}$ FA (83.05 kg ha$^{-1}$), 50% RDF + 40 t ha$^{-1}$ FA (83.89 kg ha$^{-1}$), 5 t ha$^{-1}$ FYM + 20 t ha$^{-1}$ FA (64.33 kg ha$^{-1}$) and 5 t ha$^{-1}$ FYM + 40 t ha$^{-1}$ FA (71.85 kg ha$^{-1}$).
The enhanced yield seen under these treatments may be explained by the increased potassium absorption brought on by the application of RDF together with FA. Singh & Singh (1986) [10], Hussain Saheb (1993) [4], and Rajkumar observed similar findings. (2000) [7].

**Table 3:** Effect of fly ash application on nitrogen uptake (kg ha$^{-1}$) by soybean and chickpea

| Treatments | Soybean 2019 | Soybean 2020 | Mean | Chickpea 2019-20 | Chick pea 2020-21 | Mean |
|---|---|---|---|---|---|---|
| T1:Control | 108.70$^{f}$ | 98.97$^{f}$ | 103.83$^{d}$ | 76.25$^{d}$ | 99.00$^{f}$ | 87.63$^{f}$ |
| T2:50% RDF | 167.26$^{bcd}$ | 140.60$^{bcd}$ | 153.93$^{b}$ | 121.23$^{bc}$ | 130.48$^{bcde}$ | 125.85$^{bcd}$ |
| T3:100% RDF | 233.86$^{a}$ | 173.42$^{a}$ | 203.64$^{a}$ | 148.90$^{ab}$ | 193.07$^{a}$ | 170.98$^{a}$ |
| T4:20 t/ha FA | 127.34$^{ef}$ | 108.13$^{ef}$ | 117.74$^{cd}$ | 93.84$^{cd}$ | 106.06$^{ef}$ | 99.95$^{ef}$ |
| T5:40 t/ha FA | 114.25$^{f}$ | 98.03$^{f}$ | 106.14$^{d}$ | 94.22$^{cd}$ | 101.12$^{f}$ | 97.67$^{ef}$ |
| T6:5 t/ha FYM | 152.79$^{cde}$ | 113.66$^{def}$ | 133.23$^{c}$ | 92.26$^{d}$ | 137.74$^{bcd}$ | 115.00$^{cde}$ |
| T7:50% RDF + 20 t/ha FA | 181.41$^{bc}$ | 134.36$^{cde}$ | 157.88$^{b}$ | 134.48$^{ab}$ | 139.45$^{b}$ | 136.96$^{b}$ |
| T8:50% RDF + 40 t/ha FA | 189.69$^{b}$ | 142.52$^{bc}$ | 166.10$^{b}$ | 120.98$^{bc}$ | 139.21$^{bc}$ | 130.10$^{bc}$ |
| T9:100% RDF + 20 t/ha FA | 234.80$^{a}$ | 168.52$^{ab}$ | 201.66$^{a}$ | 152.19$^{a}$ | 184.78$^{a}$ | 168.48$^{a}$ |
| T10:100% RDF + 40 t/ha FA | 246.59$^{a}$ | 157.64$^{abc}$ | 202.12$^{a}$ | 133.23$^{ab}$ | 211.34$^{a}$ | 172.28$^{a}$ |
| T11:5 t/ha FYM + 20 t/ha FA | 141.49$^{def}$ | 103.43$^{f}$ | 122.46$^{cd}$ | 90.80$^{d}$ | 110.12$^{bcdef}$ | 100.46$^{ef}$ |
| T12:5 t/ha FYM + 40 t/ha FA | 145.83$^{cdef}$ | 107.12$^{f}$ | 126.48$^{cd}$ | 98.81$^{cd}$ | 116.61$^{bcdef}$ | 107.71$^{def}$ |
| SE m (±) | 11.6 | 8.94 | 6.67 | 8.72 | 8.94 | 5.99 |
| CD (p = 0.05) | 34.01 | 26.22 | 19.78 | 25.57 | 26.23 | 17.57 |

**Table 4:** Effect of fly ash application on phosphorus uptake (kg ha$^{-1}$) by soybean and chickpea

| Treatments | Soybean 2019 | Soybean 2020 | Mean | Chickpea 2019-20 | Chick pea 2020-21 | Mean |
|---|---|---|---|---|---|---|
| T1:Control | 9.55$^{d}$ | 12.49$^{de}$ | 11.02$^{e}$ | 5.69$^{e}$ | 6.00$^{c}$ | 5.85$^{d}$ |
| T2:50% RDF | 13.68$^{bcd}$ | 16.51$^{abcd}$ | 15.09$^{cd}$ | 8.74$^{bcde}$ | 7.93$^{bc}$ | 8.34$^{cd}$ |
| T3:100% RDF | 17.71$^{ab}$ | 17.68$^{abc}$ | 17.70$^{abc}$ | 11.93$^{ab}$ | 12.66$^{a}$ | 12.29$^{a}$ |
| T4:20 t/ha FA | 10.31$^{cd}$ | 12.81$^{de}$ | 11.56$^{e}$ | 7.54$^{de}$ | 5.99$^{c}$ | 6.77$^{d}$ |
| T5:40 t/ha FA | 10.62$^{cd}$ | 11.97$^{de}$ | 11.29$^{e}$ | 7.01$^{de}$ | 6.56$^{c}$ | 6.79$^{d}$ |
| T6:5 t/ha FYM | 11.74$^{cd}$ | 13.24$^{cde}$ | 12.49$^{de}$ | 6.33$^{de}$ | 7.25$^{c}$ | 6.79$^{d}$ |
| T7:50% RDF + 20 t/ha FA | 14.76$^{bc}$ | 15.70$^{cde}$ | 15.23$^{cd}$ | 9.63$^{abcd}$ | 9.60$^{b}$ | 9.61$^{bc}$ |
| T8:50% RDF + 40 t/ha FA | 17.03$^{ab}$ | 16.00$^{bcd}$ | 16.52$^{bc}$ | 9.50$^{abd}$ | 9.51$^{b}$ | 9.51$^{bc}$ |
| T9:100% RDF + 20 t/ha FA | 19.73$^{a}$ | 20.38$^{ab}$ | 20.06$^{a}$ | 11.18$^{abc}$ | 12.18$^{a}$ | 11.68$^{ab}$ |
| T10:100% RDF + 40 t/ha FA | 18.03$^{ab}$ | 20.72$^{a}$ | 19.37$^{ab}$ | 12.15$^{a}$ | 12.95$^{a}$ | 12.55$^{a}$ |
| T11:5 t/ha FYM + 20 t/ha FA | 11.51$^{cd}$ | 11.20$^{e}$ | 11.36$^{e}$ | 5.61$^{e}$ | 6.47$^{c}$ | 6.04$^{d}$ |
| T12:5 t/ha FYM + 40 t/ha FA | 12.20$^{cd}$ | 13.99$^{cde}$ | 13.09$^{de}$ | 8.23$^{cde}$ | 8.15$^{bc}$ | 8.19$^{d}$ |
| SE m (±) | 1.04 | 0.69 | 0.98 | 1.01 | 0.65 | 0.79 |
| CD (p = 0.05) | 3.15 | 2.09 | 2.88 | 2.97 | 1.91 | 2.32 |

**Table 5:** Effect of fly ash application on potassium uptake (kg ha$^{-1}$) by soybean and chickpea

| Treatments | Soybean 2019 | Soybean 2020 | Mean | Chickpea 2019-20 | Chick pea 2020-21 | Mean |
|---|---|---|---|---|---|---|
| T1:Control | 76.99$^{e}$ | 78.57$^{cd}$ | 77.78$^{f}$ | 69.51$^{e}$ | 60.88$^{d}$ | 65.19$^{e}$ |
| T2:50% RDF | 103.37$^{bcd}$ | 94.58$^{bc}$ | 98.98$^{cde}$ | 97.31$^{bcde}$ | 77.89$^{cd}$ | 87.60$^{bcd}$ |
| T3:100% RDF | 112.81$^{abc}$ | 108.3 $^{ab}$ | 110.56$^{bc}$ | 120.88$^{ab}$ | 99.66$^{ab}$ | 110.27$^{a}$ |
| T4:20 t/ha FA | 78.24$^{e}$ | 79.84$^{cd}$ | 79.04$^{f}$ | 78.46$^{de}$ | 64.88$^{cd}$ | 71.67$^{de}$ |
| T5:40 t/ha FA | 75.60$^{e}$ | 74.47$^{d}$ | 75.04$^{f}$ | 79.50$^{de}$ | 68.00$^{cd}$ | 73.75$^{cde}$ |
| T6:5 t/ha FYM | 87.05$^{de}$ | 85.60$^{cd}$ | 86.33$^{ef}$ | 80.64$^{de}$ | 77.41$^{cd}$ | 79.02$^{cde}$ |
| T7:50% RDF + 20 t/ha FA | 102.32$^{cd}$ | 89.26$^{cd}$ | 95.79$^{de}$ | 116.04$^{abc}$ | 83.05$^{bc}$ | 99.54$^{ab}$ |
| T8:50% RDF + 40 t/ha FA | 103.09$^{bcd}$ | 108.55$^{ab}$ | 105.82$^{cd}$ | 100.78$^{bcd}$ | 83.89$^{bc}$ | 92.33$^{bc}$ |
| T9:100% RDF + 20 t/ha FA | 129.39$^{a}$ | 121.29$^{a}$ | 125.34$^{a}$ | 113.44$^{abc}$ | 109.72$^{a}$ | 111.58$^{a}$ |
| T10:100% RDF + 40 t/ha FA | 120.46$^{ab}$ | 123.77$^{a}$ | 122.11$^{ab}$ | 127.62$^{a}$ | 104.11$^{a}$ | 115.87$^{a}$ |
| T11:5 t/ha FYM + 20 t/ha FA | 78.55$^{e}$ | 84.13$^{cd}$ | 81.34$^{f}$ | 85.57$^{de}$ | 64.33$^{cd}$ | 74.95$^{cde}$ |
| T12:5 t/ha FYM + 40 t/ha FA | 80.04$^{e}$ | 84.26$^{cd}$ | 82.15$^{f}$ | 90.52$^{cde}$ | 71.85$^{cd}$ | 81.19$^{cde}$ |
| SE m (±) | 5.58 | 5.78 | 4.19 | 8.14 | 5.86 | 5.76 |
| CD (p = 0.05) | 16.35 | 16.94 | 12.29 | 23.88 | 17.19 | 16.89 |

## Conclusions

The combination application of RDF and fly ash resulted in significantly higher grain and straw yield. In comparison to control, the application of 100% RDF + 40 t ha$^{-1}$ Fly ash resulted in the maximum seed yield in soybean and chickpea. The treatment 100% RDF + 40 t/ha Fly ash showed the highest primary nutrient uptake, while the controlled treatment recorded the lowest.

## Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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