

Original Research Article

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Long-Term Effect of Fertilization and Algalization on Aggregate Stability, Aggregate Associated Carbon and Nitrogen Under Rice-Wheat Cropping System

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ABSTRACT

Keywords

Long-term, Fertilization, Algalization, Aggregate stability, BGA, Rice-wheat.

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An experiment was carried out under long term trial in randomized block design (RBD) at Indira Gandhi Krishi Vishwavidyalaya, Raipur, India to comprehend the long-term effect of fertilization and algalization on soil aggregation; C and N fractions associated with such aggregates under rice based cropping sequence. Three treatments viz. control, 50% NPK and NPK + BGA (blue green algae) were studied and results revealed that the treatments amended with 50% NPK and 50% NPK + BGA significantly enhanced soil aggregate stability and C as well as N associated with aggregates at upper and lower profile depths over control. The present experiment suggested that inappropriate nutrient management strategy under unremitting cereal- cereal (rice-wheat) cropping system resulted poor aggregate stability, lower C and N content in aggregates, whereas; the addition of suboptimal dose of NPK with or without blue green algae (BGA) gave rise to increase such properties over no fertilization.

Introduction

Indian agriculture has been perceived several methodological changes during past few decades and as a consequences, improved nutrient as well as water management practices has become the integral part of modern farming. Adaptation of such improved approaches resulted boosting crop yield but also altered soil quality. Beside soil nutrient status, soil aggregation and other physical properties were also deteriorated due to continuous intensive farming without

appropriate nutrient management. Soil aggregation contributed to productivity and structural improvement of soil (Campbell *et al.*, 2001) and is positively related with soil organic matter (SOM) content (Hati *et al.*, 2006); thus addition of organic matter in soil improved aggregation (Rose, 1991).

The influence of fertilizers on soil aggregation has also been observed by Campbell *et al.*, (2001). Furthermore,

application of composted manure led to improve more water stable aggregates in soil (Whalen *et al.*, 2003).

Carbon and nitrogen associated with water stable aggregates contributed to the soil productivity and also influenced by several factors viz. tillage (Chen *et al.*, 2009), manuring (Wortmann and Shapiro, 2007) and fertilization (Hua *et al.*, 2014), cropping system etc. Beside these, soil depth is one of the major factors affecting aggregate protected C and N in soil. These C and N fractions comprising the slow pool and are intermediate between active and passive fractions.

Rice-wheat system is major cropping system in Chhattisgarh, popularly known as rice bowl of India. The term 'algalization' is prevalently used for application of blue green algae (BGA) in rice field. There has seldom been engrossed on the influence of BGA in combination with fertilizers on soil physical properties. Hence, it was hypothesized that algalization with fertilization may be a strategic nutrient management practice for reducing nitrogen demand from off farm sources and for improvement of soil physical qualities under rice dominated cropping systems. For this purpose, the study was done with following objectives: (1) to assess the distribution of water stable aggregates in surface and subsurface soils and (2) to determine the C and N associated with those aggregates.

Materials and Methods

A long term field experiment was initiated during 1999 under All India Coordinate Research Project (AICRP) at Indira Gandhi Krishi Vishwavidyalaya, Raipur (21°4'N, 81°4'E and 293 m mean sea level), Chhattisgarh. The climate is classified as sub-humid type and the average annual

precipitation is 1317.77 mm of which mostly occurs during monsoon season (June to September). The soil order is Vertisol and dominant clay mineral is fine montmorillonite. Rice was transplanted in kharif season (first week of July) followed by sowing of wheat in Rabi season (November). Rice was harvested in October and that of wheat was done in March. The following treatments were studied in Randomized Block Design (RBD) with three replications with plot size of 20x10 m: control (no fertilization), 50% NPK (50:30:20 kg ha⁻¹ N: P₂O₅: K₂O respectively) and 50% NPK+ BGA (50:30:20 kg ha⁻¹ N: P₂O₅: K₂O respectively + 10 kg ha⁻¹ dry BGA culture in kharif (rice) crop only). The fertilizers used during 1999 to 2014 were Urea for N, single super phosphate (SSP) for P and muriate of potash (MOP) for K. It was hypothesized that in addition to fixing atmosphere nitrogen, BGA may also help to improve aggregate stability and increase slow C and N stock in soil. The soil samples were collected randomly in June 2014 after harvesting of wheat and before rice transplantation from both surface (0-15 cm) and subsurface soils (15-30 cm). The samples were dried, ground, processed and analyzed in the laboratory of Indian Institute of Soil Science, Bhopal. Aggregate separation method as described by Camberdella and Elliott, (1993) was adopted to determine sand free mass of water stable aggregates. The aggregates of >2 mm size were pre-wetted in water on the largest sieve (>2mm) fitted in Yodder's apparatus for 5 minutes before sieving. Aggregate distribution was accomplished by moving the sieve vertically in water. The >2 mm aggregates were collected in aluminum pan and dried in oven at 65 C. Soil plus water that passed through sieve was poured in next finer sieve and repeated the procedure for every sieve classes. Silt plus clay fraction was centrifuged for 10 minutes at 3000 rpm and backwashed in aluminum pan. Dried fractions

were weighed and quantified and expressed as sand free mass. The aggregates were ground to pass 0.2 mm sieve for estimating water stable carbon and nitrogen. Method suggested by Walkley and black (1934) was adopted for analysis of water stable aggregate carbon. Total N concentration associated with aggregates was determined by Kjeldahl method (Page, 1982). Sand free C and N was calculated with formula suggested by Six *et al.*, (2000) after dispersing soil with 1% sodium hexametaphosphate.

Results and Discussion

Long-term effect of fertilization & algalization on aggregate stability

A significant distribution of aggregates was recorded in both surface (0-15 cm) and subsurface (15-30 cm) soils. The small macro aggregates (2000-250 μm) were dominant fractions over all the classes followed by micro aggregates (250-53 μm) and large macroaggregates (>2000 μm). The least aggregate mass were found in silt plus clay fraction (<53 μm). Similar trend was observed in subsurface soil as well. The significant difference attributable to treatments was also observed. In surface soil, 50% NPK+BGA treatment contributed significantly large mass of aggregates in large and small macro aggregate size classes followed by 50% NPK and the least proportion of aggregates were recorded in control. Whereas; the control comprised larger proportion of soil mass in micro aggregate and silt + clay fractions (Fig. 1). Similar trend was also observed in subsurface soil, however; the difference among treatments was non-significant for silt + clay fraction (Fig.2). The graph clearly indicated that the algalization and fertilization significantly improved soil aggregation and aggregate stability in both surface and subsurface soil over control. Fertilization enhanced aggregation by its effect on plant

growth and ultimately, biomass returned to soil (Campbell *et al.*, 2001). Similarly, blue green algae formed a gluing mesh and bound soil particles consequently; promoted aggregation (Belnap, 1993; Malam Issa *et al.*, 2001). Additionally, extracellular polymeric secretions mainly composed of polysaccharides, by BGA; have also reported which acts as binding agent (Lynch and Bragg 1985). Likewise, BGA also added considerable amount of organic matter in soil (Goyal, 2002) and soil aggregation may be related with the binding effect of such organic matter.

Long-term effect of fertilization & algalization on aggregate associated carbon

Aggregate associated carbon concentrations were greater in large macro aggregates than rest of the classes in surface soil. Significant buildup of carbon was recorded in treatment amended with 50% NPK + BGA in all the aggregate size classes. However, it was at par with 50% NPK treatment in micro aggregate class and non-significant in silt + clay fraction. The lowest concentrations were observed in control. In subsurface soil, greater carbon concentrations were observed in 50% NPK + BGA treatment followed by 50% NPK and the least concentrations were recorded in control, however; the difference among the treatments were non-significant for micro aggregates and silt clay fraction (Table 1). Integrated application of organic matter with fertilizers significantly increased the aggregate associated C (Yuan *et al.*, 2013) and it might be a cause for greater C in 50% NPK + BGA and 50% NPK treatment as BGA added substantial amount of organic matter in soil while fertilizer promoted rhizospheric deposition and rhizobial activity. Similar results were also observed by Wei *et al.*, (2011). The significant greater yield of rice and wheat in treatment receiving 50% NPK + BGA and 50% NPK over control has

observed by Singh and Wanjari ((2013) and this might be contributed to greater biomass returned to soil and increased C concentration. Significant buildup of soil C fractions under fertilization and algalization has been reported (Joshi *et al.*, 2017) which

contributed to soil aggregate C. The lowest aggregate protected C content in control was also reported by Yuan *et al.*, (2013). Further, the decreasing C content in aggregate with increasing soil depth is evident (Das *et al.*, 2014) which resembled with this finding.

Fig.1 Long-term effect of fertilization and algalization on aggregate stability under rice-wheat Cropping system at surface (0-15 cm) soil

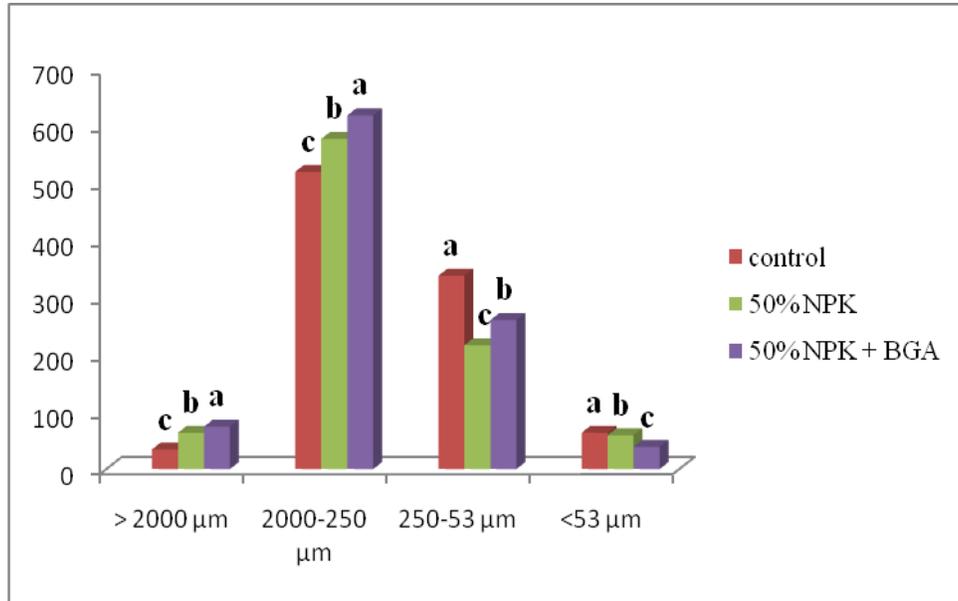


Fig.2 Long-term effect of fertilization and algalization on aggregate stability under rice-wheat Cropping system at subsurface (15-30 cm) soil

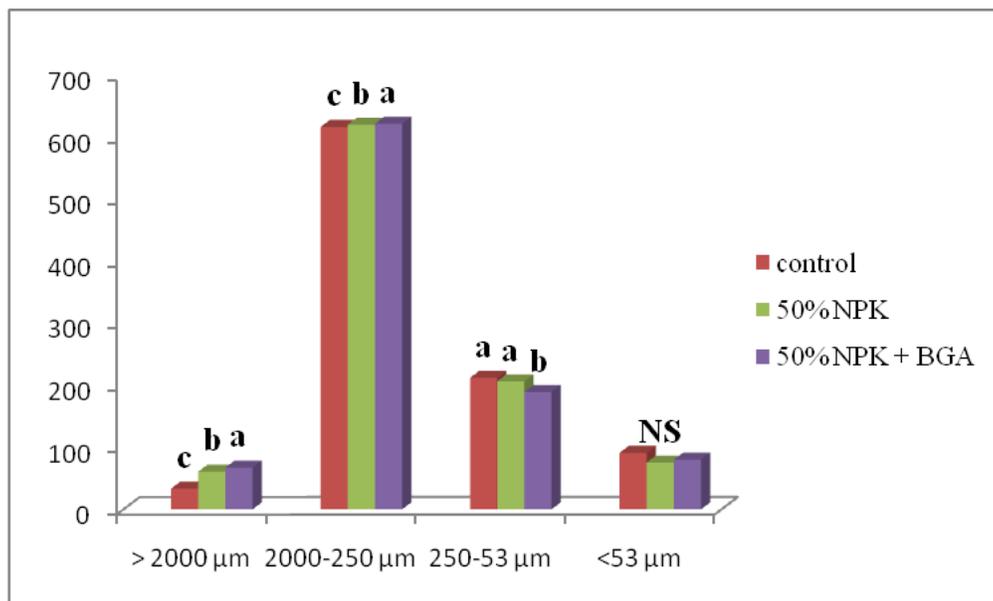


Table.1 Long-term effect of fertilization and algalization on soil aggregate Carbon under rice-Wheat cropping system at 0-15 and 15-30 cm soil depth

Carbon associated with water stable aggregates (sand free mass g kg ⁻¹)				
Soil depth 0-15 cm	>2000 μm	2000-250 μm	250-53 μm	<53 μm NS
Control	5.68 c	3.90 c	3.75 b	3.10
50% NPK	6.33 b	4.97 b	4.77 a	3.73
50% NPK + BGA	8.14 a	5.57 a	5.11 a	3.73
Soil depth 0-15 cm	>2000 μm	2000-250 μm	250-53 μm NS	<53 μm NS
Control	3.85 c	1.89 c	2.46	2.17
50% NPK	5.42 b	2.17 b	3.06	2.48
50% NPK + BGA	6.03 a	3.79 a	3.36	2.79

Table.2 Long-term effect of fertilization and algalization on soil aggregate nitrogen under rice-Wheat cropping system at 0-15 and 15-30 cm soil depth

Nitrogen associated with water stable aggregates (sand free mass g kg ⁻¹)				
Soil depth 0-15 cm	>2000 μm	2000-250 μm	250-53 μm	<53 μm
Control	0.73 c	0.52 c	0.40 b	0.31 b
50% NPK	0.79 b	0.63 b	0.60ab	0.45 a
50% NPK + BGA	0.94 a	0.72 a	0.66 a	0.50 a
Soil depth 0-15 cm	>2000 μm	2000-250 μm	250-53 μm NS	<53 μm NS
Control	0.38 b	0.17 c	0.27	0.23
50% NPK	0.51 a	0.22 b	0.34	0.24
50% NPK + BGA	0.54 a	0.44 a	0.39	0.29

Long-term effect of fertilization and algalization on aggregate associated nitrogen

Nitrogen associated with soil aggregates were recorded greater in surface soil than subsurface soil. In surface soil, treatment amended with 50% NPK + BGA contributed to greater N accumulation, however; it was at par with 50% NPK receiving treatment in silt + clay fraction. The least concentration was observed in control. In subsurface soil, 50% NPK + BGA enhanced N accumulation in all aggregate size classes. However; 50% NPK + BGA and 50% NPK treatments were statistically at par with each other in large macro aggregates, while variation was non-significant in micro aggregates and silt + clay fraction (Table 2). BGA fixed atmospheric N by using sunlight as energy source (Stewart,

1980) and thus; accelerated the aggregate protected N concentration in 50% NPK + BGA treatment over control. Potential N fixation in rice field by blue green algae was also observed by Roger *et al.*, (1993). Moreover, application of BGA with half dose of NPK also improved microbial biomass nitrogen in soil (Joshi, *et al.*, 2017). Similarly, mineral fertilizers enhanced plant growth and led to greater residual biomass return to soil which act as food substrate for microorganisms involved in N mineralization.

Greater aggregate-N concentration due to fertilizer application was also reported by Manna *et al.*, (2013). Control, as a result of continuous cropping without nutrient management led to decreased N in all aggregate fractions in paddy soil (Wei *et al.*, 2011).

In conclusion, soil parameters under rice-wheat system, as a consequence of one and half decade of continuous cropping and crop nourishment showed significant response towards nutrient addition. Soil aggregation, aggregate associated C and N concentrations were greater in treatment receiving suboptimal dose of primary nutrients over control in 0-15 as well as 15-30 cm soil depth. However, the improvement were accelerated when BGA were applied in combination with suboptimal dose of NPK. Therefore, it can be concluded from above investigation that BGA in combination with fertilizers may not only enhance the soil nutrient status but also improve stability of soil aggregates and may reduce soil loss from water erosion.

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