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Effect of panchgavya on soil chemical properties of groundnut (*Arachis hypogaea*) rhizosphere and crop productivity in western Rajasthan

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ABSTRACT

In view of the cost effectiveness and eco-friendly characteristics of the organic amendments, a field experiment was conducted on the high pH soils of arid zone of India to test the efficacy of panchgavya solution as an organic means to ameliorate sodic soil under irrigated condition. Soil application of panchgavya solution @ 3 l/m² significantly decreased the soil pH from 9.0 to 8.3 during initial 5 days period whereas it increased soil organic carbon content by 50% and availability of P, Fe, Cu, Zn, and Mn in the rhizosphere by 17 % over the control throughout the crop growth stages. The same treatment raised pod yield, haulm yield and biological yield to the tune of 85.3, 93.2 and 89.7% respectively, over the control. Similarly, foliar application of panchgavya in combination with datura (*Datura metel*) leaf extract at 1:1 also enhanced pod yield significantly over control.

Keywords: Dehydrogenase activity, Panchgavya, Sodic soil, Soil micronutrient

The arid and semi-arid lands account for 30 per cent of the world total area and are inhibited by 20 per cent of the total world population (Sivakumar *et al*. 2005). Soil alkalinity poses serious threats to agricultural productivity in arid and semiarid regions of the world. High pH of the rhizosphere is the most important limiting factors in realizing the full potential of crops grown on these soils. The reduction in availability of essential nutrients in alkaline soils is generally attributed to high *p*H of these soils (Qadir *et al*. 2006). Essential nutrient elements such as N, P, Fe, Zn, Mn, and Cu are becoming growth limiting elements in many alkaline soils (Mengel and Kirkby 2006). Although there are some corrective measures in practice for moderation of soil reaction in alkaline soils yet, acidification with H_2SO_4 and elemental sulphur (S) are most common. Besides their handling and application difficulties along with detrimental environmental effects, direct application of strong acids like, H_2SO_4 in such soils is prohibitively expensive in developing countries (Qadir *et al*. 2006). Similarly, reports from the available literatures indicate that oxidation of S to H_2SO_4 is unlikely to be sufficient in soils of high pH to warrant their large-scale reclamation. Since the *p*H of alkaline soils is usually greater than 8.0 and the microbial oxidation of elemental S would not produced sufficient quantity of H_2SO_4 for lowering the soil *p*H (Qadir and Oster 2004). In recent years, phytoremediation, biological reclamation, or organic reclamation approaches have received considerable attention in many developing countries, as these are much cheaper than chemical amendments and also environmentally sustainable (Qadir *et al*. 2006). Therefore, it was hypothesized that reduction of soil *p*H with suitable organic amendments cold increase the availability of nutrients and therefore might help in sustainable crop growth in these soils. In the present study, an attempt was made to explore the suitability of panchgavya as an effective technology for acidification of high *p*H soils. The change in soil *p*H and other properties of alkaline soil with panchgavya was tested by conducting a field experiment of groundnut (*Arachis hypogaea*) on the panchgavya treated soils under arid conditions. Soil physicochemical properties and the availability of P, Fe, Cu, Zn, and Mn in the rhizosphere were also assessed throughout the crop growth period.

MATERIALS AND METHODS

The experiment was conducted at Central Arid Zone Research Institute (CAZRI), Regional Research Station, Jaisalmer, India (26°52'N, 70°55'E and 194.50 m altitude) during 2006 and 2007 in Kharif season. The climate of the region is typically characterized by aridity of the atmosphere and salinity in the rhizosphere with extremes of temperature both in summers (May–June) and winters (January–February). During the crop growth period (26-46 standard meteorological weeks), 369 and 190 mm rainfall were received in 2006 and 2007, respectively. The soil (*p*H of 9.2) of the experimental field was sandy in texture (*Typic Torripsamments* and shallow in depth (50 cm) with 0.08% organic carbon, 72.80 kg/ha available N, 6.45 kg/ha available P, 215.78 kg/ha available K, 6.92 kg/ha available S, and 7.55% free $CaCO_3$ with pH 9.2. Concretions of CaCO3 at an average depth of 50 cm below soil surface were common characteristics of the study region.

The experiment was carried out with four levels of soil applied panchgavya (0, 1, 2, and 3.0 l/m²) in main plot and four levels of foliar applied sources (control, neem, datura and tumba to standing crop) in sub plot in a split-plot design with three replications. Panchgavya solution was prepared by thorough mixing of fresh cow dung (7 kg), cow ghee (1 kg butter oil), fresh cow urine (10 l), cow milk (3 l), cow milk curd

(2 l), jaggery (3 kg unrefined sugar from sugarcane juice) and ripe banana (2 kg) in an open plastic container. The leaf extracts of neem (*Azadirachta indica)*, datura (*Datura metal*), and tumba (*Citrullus colocynthis*) for foliar application were prepared by mixing fresh ground leaves with cow urine in 1:1 ratio followed by fermentation. The filtrates of leaf extract were mixed with the filtered panchgavya solution at the ratio of 1:1 to prepare the foliar (spray) solutions. Twenty litre filtered solutions each of *panchgavya* as well as plant leaf extracts/ha were used for a single application. The characteristics of prepared undiluted panchgavya solution had a 4.35 *p*H, 19.36 dS/m EC, 1.50% organic carbon, 5800 ppm N and 900 ppm P.

The field was prepared by ploughing with tractor drawn disc plough followed by a cross harrowing and planking to obtain a thoroughly pulverized seed bed. After a pre-sowing irrigation, 'MA-10' groundnut was sown on 15th July, 2006 and 10th July, 2007. The seeds were treated with *Trichoderma viridae* (6 g/kg seed) as prophylactic measure against seed borne diseases. Sowing was done in rows spaced at 45 cm apart with a seed rate of 80 kg/ha. Thinning of plants were done at 10 days after sowing (DAS) in order to maintain plant to plant distance of 25 cm. The initially prepared thick slurry of panchagaya solution was diluted with water by 15 times and was applied on soil surrounding the plants in rows at 25 DAS just after second irrigation. Wetting pattern of soil application of panchgavya is assumed similar to the wetting pattern of irrigation water. Infiltration test at the field experimental site indicated a steady state infiltration rate of 1.5-3.0 mm/min, which was attained within 15-20 minutes in a dry soil. From each plot, four surface soil samples (0-15 cm) were collected between two plants in a row at 1, 5, 15, and 30 days after application (DAA) of panchgavya solution and at harvest. These samples were mixed to make a single representative sample and were analyzed for *p*H, EC, SOC, available P and available micronutrients (Fe, Zn, Mn and Cu) following standard procedures. Active microbial population in the rhizosphere was also assessed by determining the dehydrogenase activity (expressed in µg of triphenyl formazone (TPF)/g dry soil) immediately after collection of soil samples by the method suggested by Casida *et al*. (1964) using 2, 3, 5-triphenyl tetrazolium chloride (TTC) as electron acceptor. Pod yield and biological yield were recorded from each plot at the time of harvest from dried plants of the crop and expressed in kg/ha.

RESULTS AND DISCUSSION

Soil reaction and electrical conductivity: The pH and electrical conductivity (EC) of the rhizosphere of groundnut at different growth stages as affected by panchgavya solution (Fig 1a, b) showed that successive increase in its level from 1 to 3 l/m^2 reduced the *p*H of the groundnut rhizosphere temporarily during initial period of 5 DAA. Similarly, EC was

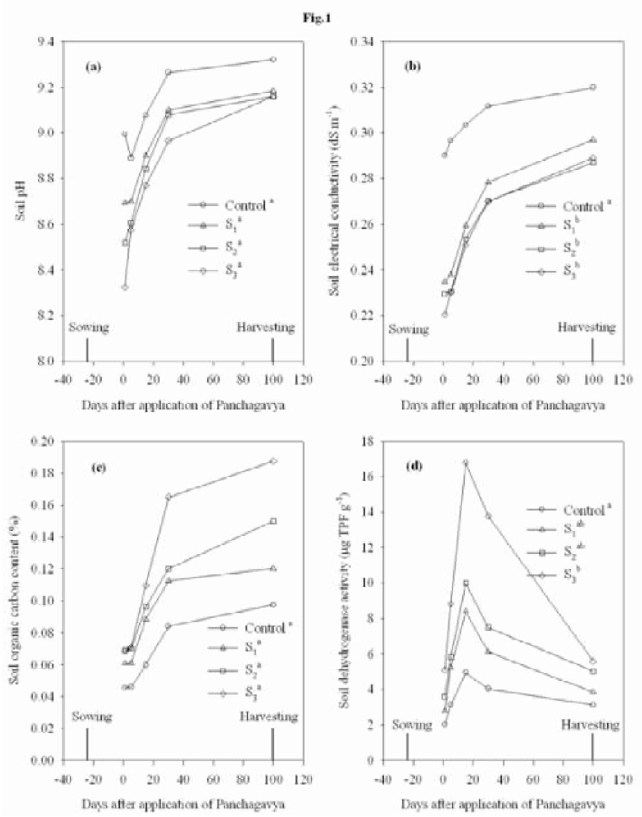

Fig 1. Effect of panchgavya on (a) soil pH, (b) soil electrical conductivity, (c) soil organic carbon content, and (d) soil dehydrogenase activity in the rhizosphere of groundnut; S1, S2, and S3 represents soil application of panchgavya @ 1 l/m^2, 2 l/ m^2, and 3 l/ m^2 row length, respectively The legends in sub-figures with dissimilar superscript are significantly different and vice-versa (Tukey's test, $p<0.05$)

also reduced considerably as that of *p*H compared to control. These effects (reduction of pH and EC) remained so up to 5 DAA and thereafter, the differences were narrowed down and became almost negligible at harvest. The reduction in *p*H of rhizosphere following application of panchgavya was due to its low *p*H (4.35). In addition, fermentation of panchgavya solution produced certain organic acids responsible for reduction of *p*H of the solution. Similar findings was reported by Kumawat *et al*. (2012) and it was argued that organic acids formed during fermentation of panchgavya by *Lactobaillus*, *Saccharomyces*, *Streptomyces*, *Rhodopseudomonas* and *Aspergillus* could have reduced the *p*H of both the formulation and soil rhizosphere. The reduction in soil EC after panchgavya application might be due to its inherent capacity to supply soluble salts of Ca^{++}, Mg^{++} and SO_4 which in soil exchange complex formed soluble salts (Na_2SO_4) with Na. These soluble salts may either be taken up by crop plants or leached out from the rhizosphere with irrigation water (Singh 1996).

Soil organic carbon and dehydrogenase activity: The study soil was having low SOC (0.08%). Thus, SOC of groundnut rhizosphere increased considerably with panchgavya (Fig 1c). Although SOC in the groundnut rhizosphere was not improved significantly at its varying levels during 1 to 5 DAA yet, SOC content increased sharply after 5 DAA with the maximum increase was observed at 3 l/m^2. The plot with soil application of panchgavya at 3 l/m^2 had 53, 54, 82, 96, and 92 per cent higher OC content at 1 DAA, 5 DAA, 15 DAA, 30 DAA and harvest, respectively over those in control plot. The observed increase in SOC might be due to supply of available OC through panchgavya (with 1.5% OC) (Kumawat *et al.* 2010). The lower content of soil OC during early period might be due to increased uptake of easily available organic matter by rapidly growing microbial population (Mishra *et al.* 2001). It was also reported that soil OC is negatively correlated with high soil *p*H (Pal and Shurpali 2006) and hence, application of panchgavya might have increased soil OC by reducing the soil *p*H.

The dehydrogenase activity of soil as affected by panchgavya application showed that panchgavya treated soils had lowest dehydrogenase activity during initial crop growth stages which increased sharply and reached maximum at 15 DAA (Fig 1d). Among all the panchgavya levels, soil application @ 3 l/m^2 recorded the highest soil dehydrogenase activity during all crop growth stages of groundnut. Moreover, the dehydrogenase activity of soil is directly related to the soil microbial population (Wlodarczyk *et al.* 2002). In this study however, lower dehydrogenase activity in the soil was observed following both low SOC content and low soil microbial activity. After addition of panchgavya, the dehydrogenase activity was increased which might be due to addition of OC and build up of microbial populations in the rhizosphere. Furthermore, the supply of readily available nutrients in soil through panchgavya solution increased the soil microbial population significantly (Gaind *et al.* 2006) and thus, increased dehydrogenase activity. Moreover, the declined trend in the dehydrogenase activity after 15 DAA of panchgavya might be due to concomitant increase in soil *p*H and formation of recalcitrant (difficultly decomposable) soil OC.

Nutrient availability in the rhizosphere: The significant effect of soil applied panchgavya solution on availability of P is also evident (Fig 2). The effect of panchgavya solution on availability of P was more pronounced during early days of application (up to 5 DAA) and decreased consistently with time and reduced to a level similar to that in control at harvest. However, the availability of Fe, Zn, Mn, and Cu was found considerably higher over the control during entire crop growth period (Fig 3). Evidently, soil application of panchgavya @ 3 l/m^2 also increased the availability of P, Fe, Cu, Zn, and Mn of all the panchgavya levels applied (Kumawat *et al.* 2010). However, the availability of all these micronutrients decreased

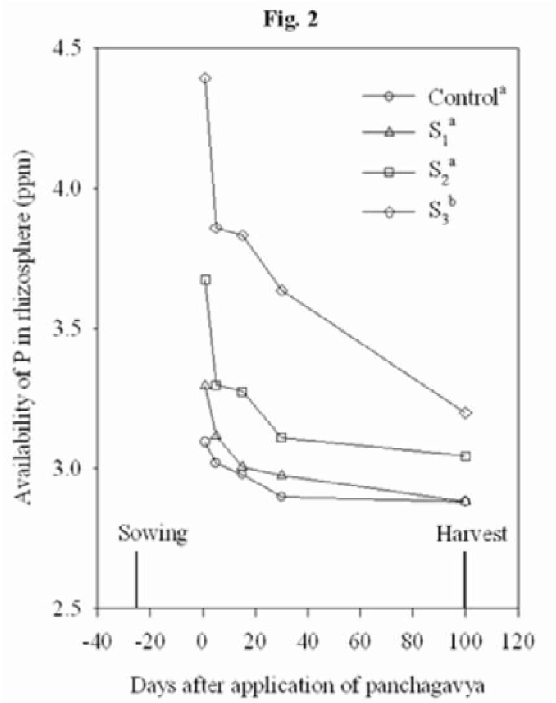

Fig 2. Effect of panchgavya on availability of phosphorus (P) in the rhizosphere of groundnut; S1, S2, and S3 represents soil application of panchgavya @ 1 l/ m^2, 2 l/ m^2, and 3 l/ m^2 row length, respectively The legends in sub-figures with dissimilar superscript are significantly different and vice-versa (Tukey's test, $p<0.05$)

with increase in *p*H of the rhizosphere indicating the fact that the availability of nutrient is *p*H dependant; and the availability of P and Cu was more sensitive to increase in soil *p*H followed by Zn during all the crop growth stages. Nevertheless, the availability of Fe and Mn showed comparatively more resilience with change in soil *p*H. Thus, observed increase in the availability of P, Fe, Cu, Zn, and Mn due to panchgavya application might be associated with several contributing factors such as increase in soil OC content, moderation in soil *p*H and soil microbial population. Increased content of organic compounds in soil after application of panchgavya could also have reduced the P fixation capacity of the soil through release of organic acids and thus, increased the P availability (Tarafdar *et al.* 2002). Application of panchgavya in soil also reduced soil *p*H and thus, increased the availability of Fe, Cu, Zn, and Mn either by increasing their solubility or by decreasing their oxidation state. Since availability of micronutrients to the plants is related to their solubility which in turn depends on soil reaction, the oxidation state of the element and organic matter content in the soil solution (Bradl 2004).

Pod yield and economics: The pod, haulm, and biological yield per hectare showed positive responses to panchgavya application (Table 1). Soil application of panchgavya solution

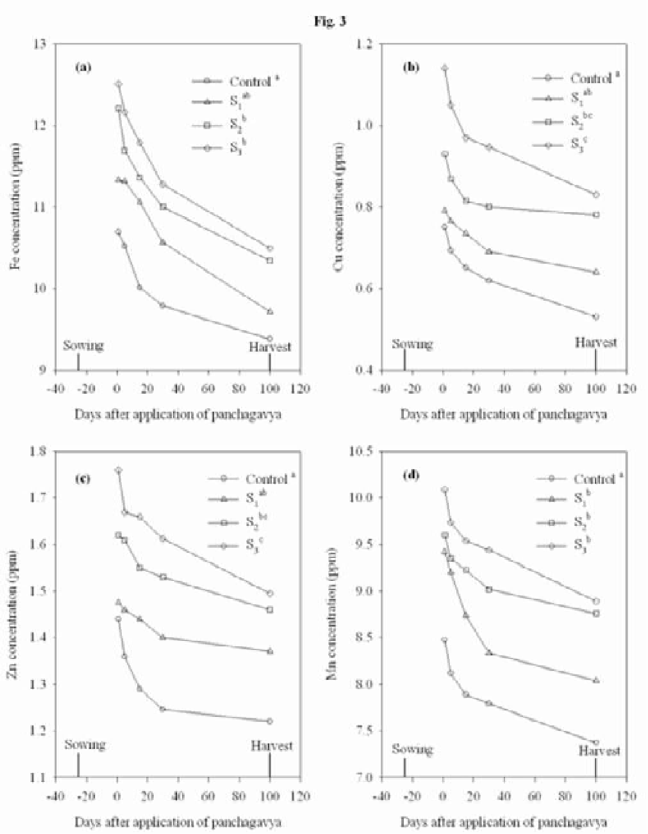

Fig 3. Effect of panchgavya on micronutrient availability in the rhizosphere of groundnut; (a) Fe concentration, (b) Cu concentration, (c) Zn concentration, and (d) Mn concentration; S1, S2, and S3 represents soil application of panchgavya @ 1 l/ m^2, 2 l/ m^2, and 3 l/ m^2 row length, respectively The legends in sub-figures with dissimilar superscript are significantly different and vice-versa (Tukey's test, $p<0.05$)

@ 3 l/m^2 increased pod yield (from 1266 to 2347 kg/ha), haulm yield (from 1532 to 2960 kg/ha) and biological yield (from 2798 to 5307 kg/ha) significantly over the control. The observed increase in the pod and biological yield following panchgavya application might be due to improvement in soil health, which was evident through increase in availability of micronutrients and soil microbial population, and decrease in soil *p*H and EC. Since the applied panchgavya solution had appreciable amount of cytokinin, it would have been directly associated with synthesis of chlorophyll in plants (Kumawat *et al*. 2012, Kumawat *et al*. 2010). Therefore, the increased nutrient supply through panchgavya increased the chlorophyll content and consequently elevated the rate of photosynthesis. Furthermore, application of panchgavya increased the soil microbial population that could have secreted some phytohormones like, auxin, cytokinin etc. having stimulatory effect on the plant growth (Ravusaheb 2008, Qadir and Oster 2002). The application of panchgavya could have possibly increased the solubility of the Ca and P in rhizosphere which were the key nutrients for the formation and development of the pod shells of groundnut (Kumawat *et al*. 2010). The data on economics also revealed that soil application of panchagavya @ 3 l/m^2 (on par with panchgavya @ 2 l/m^2 with net return of 41771/ha) had significantly higher net return of 40110/ha (Table 1) over control (26801/ha).

On foliar application, it was observed that pod yield/ha was significantly higher (22%) with panchgavya in conjunction with datura leaf-extract over other foliar solutions (Table 2) due to increased chlorophyll content, nitrate reductase activity, root nodule weight and plant nutrients although significantly higher haulm yield was evident with the foliar application of panchgavya plus neem leaf extract. The biological yield however, remained similar for both neem and datura leaf-extract based foliar solutions of panchgavya.

Table 1: Effect of soil applied panchgavya and foliar applied leaf extracts yield and economics of groundnut

Treatments	*Quantity of panchgavya (l/ha)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)	Total cost (₹ /ha)	Gross return (₹ /ha)	Net return (₹ /ha)
Levels of soil applied panchgavya							
Control	0	1266	1532	2798	16518	43319	26801
One litre/m^2	648	1721	2320	4041	24576	59887	35311
Two litre/m^2	1296	2149	2814	4962	32635	74405	41771
Three litre/m^2	1944	2347	2960	5307	40693	80803	40110
SE(±)	-	42	37	79	-	1989	557
CD (P=0.05)	-	130	113	242	-	6881	1927
Sources of foliar application							
Control (spraying of water)	0	1676	2047	3722	28268	57412	29145
Panchgavya plus Neem leaf-extract	20	1917	2704	4621	28718	67187	38470
Panchgavya plus Datura leaf-extract	20	2050	2469	4519	28718	70097	41380
Panchgavya plus tumba leaf-extract	20	1840	2406	4247	28718	63717	34999
SE(±)	-	41	35	76	-	1948	521
CD (P=0.05)	-	116	100	215	-	5687	1520

*Quantity of panchgavya excluding dilution with water (15 times with water); Interaction is non-significant

Similarly, higher net return of Rs 41380/ha was recorded with foliar applied datura plus panchgavya.

Thus, it is suggested that panchgavya application in crop rows could possibly be recommended for yield improvement in groundnut grown in a high *p*H soil as it helped in temporarily moderation of undesirable soil chemical properties.

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