ASSESSMENT OF ZINC FLOW CYCLE IN DAIRY BUFFALO: A CASE STUDY ON LOW INPUT RURAL SOIL-PLANT-ANIMAL INTERACTION IN SEMI-ARID ZONE OF TELANGANA, INDIA

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ABSTRACT

In dry areas, ruminants mainly graze on native grasses, crop residues and by-products of agro industry and suffer from mineral deficiencies. Present investigation was carried out to explain the Zinc (Zn) flow in semi-arid resource driven areas, Kandlapally, Gangupalle and Yenkepally in Ranga Reddy district, Telangana, India in soil to soil through livestock cycle and suggest suitable measures to prevent its losses as well as alleviate Zn deficiency in dairy buffaloes. Ten farmers from each village rearing buffaloes were randomly selected for collection of samples (soil, plant, blood, faeces, urine and milk) and Zn of samples were analyzed with an atomic absorption spectrophotometer after suitable processing. It was observed that the 45% soil samples and most of the straws and stovers of the study area were classified as below critical level for Zn. Green fodder (Hybrid Napier Co-4 variety, Fodder sorghum, Grazing grass), tree leaves and concentrate ingredients were having sufficient Zn content. The buffalo serum Zn content in the samples were adequate, but 26.6% of the samples were having below critical level of Zn which suggests sizable amount of buffaloes suffering from Zn deficiency. Significant correlation values were obtained between feed and fodder and buffalo serum, however, such correlations were not observed between the mineral levels in buffalo and mineral levels in soil. Zn content in green fodder were more representative of soil, faeces and urine ($R^2 = 0.267$) than only soil ($R^2 = 0.039$) which suggests true recycling of nutrients through faeces and urine under rural semi-arid conditions. Based on soil, forage, feed, water and animal samples analyses, it was concluded that few sample was deficient in Zn, but animal was able to maintain the plasma Zn level to some extent (about 74%). Zinc homeostasis is largely regulated by its uptake and loss through the small intestine. Supplementation of Zn is required to overcome sub-clinical Zn deficiency mainly through feed fortification.

Keywords: soil-plant-animal continuum, micro-minerals, semi-arid agro ecosystem, zinc profile, fodder, *Bubalus bubalis*, buffalo

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INTRODUCTION

Micronutrient deficiencies have been reported to be one of the main causes for yield plateau or even yield decline in intensified cropping systems (Katyal and Rattan, 2003). Uptake of micronutrients is affected by the presence of major nutrients due to either negative or positive interactions. Continuous use of high analysis fertilizers under intensified cropping and neglect of organic manures manifested the occurrence of widespread micronutrient deficiencies, especially of Zinc (Zn) in light-textured soils of India after 1960s. Zn deficiency has increased from 44% to 48%, and is expected to further increase up to 63% by 2025 (Singh, 2009). In southern India, Zn deficiency is a predominant problem in 58%, 73% and 83% soils of Andhra Pradesh, Karnataka and Maharashtra, respectively, due to low organic matter, high clay and calcium carbonate (Srinivasarao *et al*., 2013). Zn deficiency is frequently observed in swell-shrink soils in these states. In a recent study, geographic information system (GIS)-generated thematic maps have indicated that 10% of the total geographical area is affected by Zn deficiency (Bali *et al*., 2010).

Most of the rainfed soils are degraded in the form of runoff and low organic carbon thus resulting in emergence of deficiencies of micronutrients such as Zn, Fe, manganese (Mn), copper (Cu), B and molybdenum (Mo). Extensive Zn deficiency in soils of semi-arid tropics of India was reported (Rego *et al*., 2007; Srinivasarao *et al*., 2008). Of the microelements, Zn is the most widespread productivity constraint in rainfed production (Srinivasarao *et al*., 2009). The deficiency of micronutrients may emerge when the supply of micronutrients to the soil is less compared to removal through crop harvest which in turn limits crop productivity (Shukla *et al*., 2009).

In India, majorities of our livestock are reared by poor farmers for their livelihood and don't have resources to feed their livestock to optimal level and practice of supplementing mineral mixture is very limited (Pankaj and Ramana, 2013). Mineral level of grazing livestock is influenced by the mineral status of soils and forage. In dry areas, ruminants mainly graze on native grasses, crop residues and by-products of agro industry and in these grazing conditions ruminants suffer from mineral deficiency, as these food sources has less amount of minerals in them and contained imbalanced mineral level (Vijchulata *et al*., 1983; Hayashi *et al*., 1985; Fujihara *et al*., 1992; Pankaj *et al*., 2013a). In addition to soil and forages, blood plasma is the best source for estimation of mineral status in the animals (McDowell, 1985; Khan *et al*., 2006). Zn, being a critical mineral for livestock productivity, has not been studied systematically about its flow from soil to soil through plant and animal in rainfed areas. The review suggested that Zn is very important mineral to impart heat tolerance in livestock (Ramana *et al*., 2000; Pankaj *et al*., 2013b) which is the biggest challenge in semi-arid tropics. Under this climate change scenario there is urgent need to decipher the Zn flow in livestock to suggest suitable mineral supplementation strategies for farmers rearing livestock under rainfed conditions which is more resource dependent and vulnerable to environmental stressors (Banik *et al*., 2015). Keeping in view the above facts, present investigation was carried out to explain the Zn flow in semi-arid resource driven areas in soil to soil through livestock cycle and suggest suitable measures to prevent its losses as well as alleviate Zn deficiency in dairy buffalo.

MATERIALS AND METHODS

Description of study area

This study was conducted in three villages, namely (Kandlapally (17°17'38.5"N 78°01'25.5"E), Gangupalle (17°18'25.4"N 77°58'59.2"E) and Yenkepally (17°18'43.5"N 77°58'29.1"E) in Pudur mandal, Ranga Reddy district, Telangana, India (Figure 1). The climate of the district is characterized by a hot Summer and is generally dry except during the south west monsoon season. The district has a normal Rainfall of 781.0 mm, the bulk of which is received through the south west monsoon during the period from June to September. The mean maximum temperature begins to raise from the middle of February and reaches a maximum of about 40°C in May. With the onset of the south-West monsoon into the District early in June, there is appreciable drop in temperatures. In the beginning of November, the decrease in both the day and night temperature is rapid. December is the coldest month with the mean daily maximum temperature at 28.6°C and the mean daily minimum temperature at 13.6°C. During the South-West monsoon season the relative humidities are generally high, ranging between 70 and 80% on the average. Humidity decreases from the post-monsoon season onwards. The driest part of the year is the summer season when the humidity is generally between 30 and 35% in the afternoon. In summer, temperature during the day time ranges from 24 to 49ºC, while during winter the minimum temperature lowers down to 8ºC. The altitude of the area is 590 meters above sea level.

Collection of samples

In the study area, buffaloes are reared on local vegetation, forages and wastes of agriculture

Figure 1. Location of three villages in this study Kandlapally, Ganupalle and Yenkepally in Pudur mandal, Ranga Reddy district, Telangana, India.

products. Ten farmers from each village rearing buffaloes were randomly selected for collection of samples and information on available feeds and fodder and feeding practices followed in buffalo rearing. Samples of soil at a depth of 20 cm were collected randomly for analysis especially from real grazing areas of buffaloes (n=60). Forage samples were also taken concurrently along with the soil sampling after careful observation of the grazing behaviour of the ruminants. Drinking water samples were taken in borosilicate vials from pans. Samples of green and dry fodder, concentrate ingredients, etc were collected randomly (n=15) from farmers in each village. Similarly blood samples (n=60), urine samples (n=60), faecal samples (n=60) and milk samples (n=60) from milking buffaloes were also collected.

About 10 ml blood was collected from jugular vein using 20 ml disposable syringe in a sterilized test tube without any anticoagulant and kept at room temperature without disturbing it. After, 2 to 4 h the clots were broken with the help of pasture pipette and serum was collected using micropipette in micro centrifuge tubes and properly labelled and brought in ice pack and stored at -4°C in refrigerator.

Fecal samples were collected from the rectum of the animals manually and urine samples collected *via* manual stimulation of the vulva of female animals and a 10 ml aliquot was transferred to a polyethylene tube, acidified with 0.3 ml concentrated HCl, and frozen for subsequent analysis. The faecal samples were kept in open bags and allowed to dry in the sun under constant atmospheric moisture (<30%). Milk samples were collected in 125 ml plastic bottles using the first drawn milk. Milk samples were taken in plastic vials and stored frozen until analysis (Fick *et al*., 1979).

Processing of samples for analysis

Soil samples were air dried, crushed and sieved though 2 mm sieve. Soil samples were dried at 70ºC in an oven and ground with the help of mixer and grinder and sieved through 1 mm mesh. Dried soil samples were subjected to Mehlic-1 extracting solution method (0.05 N HCl+0.025 N H_2SO_4) following Rhue and kidder (1983). Water and urine samples were filtered into sterilized plastic beakers and 1 ml aliquots were used to prepare serial dilutions for analysis. To prepare samples for estimation of zinc, representative dried and ground samples of about 2 g each of forages, feed and faeces were digested by nitric acid and perchloric acid (3:1) at 250°C until the solution changed to colorless and thick white fumes appeared in the flask. The contents of the flask were washed with pure water and diluted to constant volume. The supernatant obtained from centrifugation was used for analysis (Koh and Judson, 1986; Neathery *et al*., 1990). Direct dry or wet ashing of plasma and milk was not possible because of high fat, protein and moisture as spattering and swelling might result in loss of sample. Therefore, appropriate quantity of each plasma and milk sample was taken into crucible after thawing. To predigest, the samples were pre-treated with 50% HNO3 over an electric heater until smoking ceases to char the majority of organic matter. These samples then were ashed for 6 h at 550ºC in a muffle furnace. The residues were dissolved in 1% HCl and transferred into a volumetric flask to make up a constant volume of 50 ml. Zn of samples were analyzed with an atomic absorption spectrophotometer.

Statistical analysis

The obtained data was subjected to statistical analysis (Steel and Torrie, 1980) and statistical significance was tested at 0.05 and 0.01

levels of probability using the SAS 9.2 software as per the standard procedure (Snedecor and Cochran 1989). Correlation coefficient of Zn content in soil, plant, and animal was determined from the data for Zn levels of soil, fodder, and blood serum. The regression equations on the relationship among soil-plant, plant-animal, and soil-plant-animal were determined using linear regression model. Microsoft Excel 2007 software was used to plot the graphs.

RESULTS AND DISCUSSION

The study has been performed in a semi arid region of Telangana, India, the climate of which will certainly influence the mineral composition of soils and forages as well as the animal's metabolism. Therefore, results obtained only concerned buffaloes rearing in such region and under such sub tropical or hot semi arid conditions.

Soil, water, forage, plasma, faeces, urine and milk zinc concentrations were compared to establish critical values to determine the various categories of deficient levels. The critical level for soils indicates the zinc concentration below which normal growth and/or mineral composition of forage may be adversely affected. For forage samples, it indicates the lowest requirement of the element or organic constituent to avoid deficiency symptoms in animals. Plasma critical levels indicate the concentration below which specific signs of deficiency may occur. Interpretation of these critical values was done with caution taking into consideration the management, nutritional, environmental and individual factors that affect the availability, supply and utilization of this nutrient.

Existing feeding practices

Most of the farmers in Yenkepally, Gangupalle and Kandlapally village, Pudur Mandal, R.R. District used to take their dairy animals for grazing on available grazing /forest/ waste lands. Few farmers kept their animals stall fed either at home or at farm nearby their cultivated lands. Sorhum and maize stovers were the most common basal feed, followed by brans. The sorghum (especially SSG-59-3 variety) was most cultivated green fodder followed by Hybrid Napier (CO-4) and and local mixed grasses. The usage of concentrate ingredients *viz.,* rice bran, GN cake, wheat bran, ground nut cake, gram chuni, maize grain, horse gram being practiced by few farmers and restricted to productive animals only. The farmers supplemented rarely mineral mixture.

Soil zinc

Based on the critical levels reported for soils, it was observed that the 45% soil samples of the study area were classified as below critical level for Zn (Table 1). The general critical levels of Zn deficiency in soils and crops fall in the range of 0.6 to 1 mg kg-1 and 10 to 20 mg kg^{-1} in dry matter, respectively (Katyal and Rattan 2003) but vary with soils and crops. Extractable soil Zn concentrations were adequate (1 mg/kg) in more than 50% of samples (Rhue and Kidder, 1983) enough for normal plant growth. These values fall within the range of those reported by Tiffany *et al*. (2001); Tejada *et al*. (1985, 1987). These extractable soil Zn concentrations above the critical level provide adequate Zn for plant growth (Rhue and Kidder, 1983).

Zinc content of feed, fodder and water

These findings revealed that the status of Zn in soil and fodder are falling in range of

marginal to deficient level. Most of the straws and stovers contained Zn well below the critical level (<30 ppm) and it is reported to be most deficient in many geographical zones of India (Garg *et al*., 2005).

All the samples of dry fodder (maize and sorghum stover) were deficient in Zn based on critical level values (30 ppm). After grazing, dry fodder is mostly the feed source for buffaloes giving less that 6 litres of milk per day, making them vulnerable for Zn deficiency.

Green fodder (Hybrid Napier Co-4 variety, Fodder sorghum, Grazing grass) were having sufficient Zn content and only few samples (12.5 to 21.4%) were having below critical level of Zn. Even tree leaves which were offered to animals were having sufficient Zn content. No tree samples were deficient in Zn level which suggested a good scope of offering tree leaves in Zn deficient areas.

All the concentrate ingredients (GN Cake, Maize grain, Conc. Mix) were having adequate Zn content. Low productive buffaloes are scarcely given concentrate making them vulnerable to Zn deficiency. This study suggests that concentrate feeding is an important mean to combat Zn deficiency.

Zn content in drinking water was very less (0.79 ppm) and were believed to be contributing least to the Zn intake to buffaloes. This suggests that Zn is mostly found in complex form and availability in water is restricted.

Forage Zn concentration was also found above the requirements of ruminants (30 mg/kg). The feed and water Zn levels were found to have contributed major part of the ruminant Zn requirements. The feed Zn content was less than the requirements for buffaloes, but below the maximum tolerable levels. A number of factors including soil, plant species, pasture management and climate may affect the likelihood of Zn deficiency in ruminants. Cox (1973) reported the low level of Zn in soil and plants. Plant maturity has also been reported to affect Zn concentration of forage and it also depends upon the tissue type of plants (Underwood, 1981; Kabata-Pendias and Pendias, 1992).

The mineral content of the fodders depend upon the type of the soil and environmental conditions they are grown (Beeson and Matrone 1976; McDowell *et al*., 2005). Only a fraction of minerals present in soil is taken up by plants depending upon geophysical/chemical composition (Reid and Horvath, 1980). Low concentration of particular mineral in soil will lower the mineral content in plant grown on such soil; however, the soil rich in a particular mineral may not result in its higher level in the plant, due to uptake mechanism existing in the roots (McDowell *et al*., 2005). Though the animals showed adequate serum concentration of Zn, they are predisposed to deficiency by the scarcity of fodders during the certain months (Pankaj and Ramana, 2013; Ramana *et al*., 2000)

Animal Zn content

The buffalo serum Zn content in the samples were adequate, but 26.6% of the samples were having below critical level of Zn (Table 1) which suggests sizable amount of buffaloes suffering from Zn deficiency. Mean values of Zn in the serum of animals fall in the category of adequate range as given by Kincaid (1999).

Buffalo milk was found to be the good source of Zn, which suggests increased Zn requirement during lactation period due to outpouring of Zn through milk.

Buffalo faecal samples were high in Zn content which may be contributing immensely

to the recycling of Zn in nature through soil and plants. Like water, buffalo urine had very limited quantity of Zn (Table 1). Zn content of faeces indicated the pasture Zn levels. A significant association between Zn concentration of pasture and in the faeces of buffaloes was observed in the study. Similar results were reported by Kumaresan *et al.* (2010) in subtropical hill agro ecosystem.

Soil-plant-animal relationship

Zn showed negative correlation between soil and plant and soil and animal, however, between plant and animal, Zn showed positive correlation. This emphasizes the involvement of different factors which affect the availability of micro minerals from soil to plants and thence to animals. The mineral content of the fodders depend upon the type of the soil and environmental conditions they are grown (Beeson and Matrone 1976; McDowell and Arthington, 2005). Only a fraction of minerals present in soil is taken up by plants depending upon geophysical/chemical composition (Reid and Horvath 1980). Low concentration of particular mineral in soil will lower the mineral content in plant grown on such soil; however, the soil rich in a particular mineral may not result in its higher level in the plant, due to uptake mechanism existing in the roots (McDowell and Arthington, 2005).

Significant correlation values were obtained between feed and fodder and buffalo serum, however, such correlations were not observed between the mineral levels in buffalo and mineral levels in soil (Table 2). In fact, no animal or plant factors were significantly correlated with soil Zn content.

Serum Zn content has a highly significant ($P<0.01$) correlation with milk and faecal Zn content (Table 2) which suggests that even if we are not taking blood from buffaloes, which is very difficult under field conditions as well as its very difficult to convince farmers for pricking of their animals for blood collection, milk or faecal collection (non-pricking) can suggest Zn status of animal.

Urinary Zn content was found to be significantly ($P<0.05$) correlated with drinking water Zn content (Table 3) which may be suggestive of urinary contamination of drinking water point.

Zn content in body fluids as regressed from various components

Zn content in green fodder were more representative of soil, faeces and urine ($R^2 = 0.267$) than only soil ($R^2 = 0.039$) which suggests true recycling of nutrients through faeces and urine under rural semi-arid conditions (Table 3). No feed component (dry fodder, green fodder and concentrate) were true representative of soil in terms of Zn flow as R^2 value varies between 0.006 to 0.039. Plant to animal continuum was sufficient enough to represent the true regression of plant Zn content into animal serum Zn content ($R^2 = 0.300$). Even milk Zn content can very well be predicted from serum and feed mix ($R^2 = 0.356$).

Zinc homeostasis

More than 90% of the Zn supplied to the buffaloes under study are through feed and fodder (Table 4). Almost 50% of Zn intake is going out of the body of buffaloes through faeces, urine and milk (Table 5) which suggests need to tap the run off Zn from body of buffalo in means of faeces, urine and milk.

In low and medium yielding buffaloes, majority of Zn is coming from green fodder, whereas, in high yielding buffaloes, majority of Zn is coming from concentrates (Figure 2). This observation suggests importance of grazing and

Table 1. Zn content (on DM basis) in soil, water, plant and animal.

Particulars	Soil	Water	Plant									Animal			
			Dry fodder		Green fodder				Concentrate						
			Maize Stover	Sorghum Stover	H.Napier (Co-4)	Sorghum	Grazing grass	Tree leaves	GN Cake	Maize grain	Conc. Mix	Serum	Milk	Faeces	Urine
Mean	1.20	0.79	15.65	15.27	46.47	37.76	25.87	67.45	64.47	29.99	50.43	1.56	3.81	58.23	0.54
SE	0.15	0.14	0.49	0.65	2.11	2.78	1.96	4.90	2.14	1.54	3.37	0.15	0.11	1.33	0.03
Minimum	0.24	0.26	9.56	7.36	22.15	13.25	12.34	34.56	43.65	16.59	19.56	0.29	2.1	42.56	0.23
Maximum	5.38	4.88	26.89	28.46	98.33	58.32	44.12	103.20	91.23	45.12	78.23	3.63	5.41	72.15	0.97
Count (n)	60	44	56	56	56	24	24	24	24	24	24	60	60	44	44
Critical level (ppm)*	1.00	-	30									0.80		40.00	
% of samples below critical level	45	-	100	100	21.4	16.6	12.5	0	0	12.5	12.5	26.6	-	0	-

*Narwal *et al.*, 2013; McDowell (1983); Rhue and Kidder (1983)

Table 2. Soil-plant-buffalo relationship (correlation) with respect to Zinc status.

Particulars	Soil	Water	Dry fodder	Green fodder	Concentrate	Serum	Milk	Faeces	Urine
Soil	1								
Water	0.217	1							
Dry fodder	0.150	0.171	1						
Green fodder	-0.197	0.195	0.202*	1					
Concentrate	-0.077	-0.155	0.195	0.325**	1				
Serum	-0.075	0.108	0.288*	0.529**	0.326*	1			
Milk	0.112	0.190	0.051	0.204	0.283*	0.554**	1		
Faeces	-0.077	0.076	0.349*	0.435**	0.260	0.707**	0.601**	1	
Urine	-0.227	-0.362*	-0.006	-0.181	0.090	0.135	-0.303*	-0.010	1

**Significant at 1% level of significance, *Significant at 5% level of significance (2-tailed)

Table-3. Regression equations on soil-plant-buffalo continuum in relation to Zinc status.

Regression equations on soil-plant-buffalo continuum in relation to Zinc status	R^2 value
Regression equation for prediction of Zn content in green fodder based on Zn content in soil	
Zn content in green fodder = 49.885 - 2.628 x (Zn content in soil)	0.039
Regression equation for prediction of Zn content in dry fodder based on Zn content in soil	
Zn content in dry fodder = 15.181 - 0.482 x (Zn content in soil)	0.022
Regression equation for prediction of Zn content in concentrate based on Zn content in soil	
Zn content in Concentrate = 49.331 - 1.291 x (Zn content in soil)	0.006
Regression equation for prediction of Zn content in buffalo serum based on Zn content in green fodder	
Zn content in buffalo serum = -0.126 + 0.038 x (Zn content in green fodder)	0.280
Regression equation for prediction of Zn content in buffalo serum based on Zn content in dry fodder	
Zn content in buffalo serum = 0.291 + 0.085 x (Zn content in dry fodder)	0.083
Regression equation for prediction of Zn content in buffalo serum based on Zn content in concentrate	
Zn content in buffalo serum = 0.746 + 0.019 x (Zn content in concentrate)	0.107
Regression equation for prediction of Zn content in buffalo serum based on Zn content in soil and feed mix	
Zn content in buffalo serum = -0.638 + 0.032 x (Zn content in green fodder) + 0.033 x (Zn content in dry fodder) + 0.005 x (Zn content in concentrate)	0.300
Regression equation for prediction of Zn content in buffalo milk based on Zn content in feed mix and serum	
Zn content in buffalo milk = 3.540 - 0.010 x (Zn content in green fodder) - 0.032 x (Zn content in dry fodder) + 0.009 x (Zn content in concentrate) + 0.525 x (Zn content in buffalo serum)	0.356
Regression equation for prediction of Zn content in green fodder based on Zn content in soil, buffalo faeces and urine	
Zn content in green fodder = 8.521 - 2.965 x (Zn content in soil) + 0.790 x (Zn content in faeces) - 7.587 x (Zn content in urine)	0.267

Table 4. Average level of Zinc (ppm) supplied to buffaloes *viv-a-vis* their requirements.

Sources	DM intake (Kg)			Zn in feed (ppm)	Zn supplied through feed to buffalo (ppm)			Zn supplied through water (ppm)			Zn requirement in ppm*			Zn deficiency in ppm		
Groups	**A#**	**B#**	**C#**		**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Concentrates																
Maize grain	2	1	0.5	29.99	59.98	29.99	14.995									
GN cake	1	0.5	0.5	64.47	64.47	32.235	32.235									
Rice polish	1.5	0.5	0.5	65.59	98.38	32.795	32.795									
Dry fodder																
Paddy straw	2	2	1.5	13.68	27.36	27.36	20.52									
Sorghum stover	2	2	1.5	15.27	30.54	30.54	22.905									
Green fodder																
Sorghum	2	2.5	2	37.76	75.52	94.4	75.52									
Hybrid Napier (Co-4)	2	2.5	2	46.47	92.94	116.175	92.94									
Total	12.5	11	8.5		449.2	363.5	291.9	47.4	39.5	35.5	1000	880	680	503.4	477.0	352.5

*Arora (1981)

#Groups A means buffaloes giving more than 10 L of milk, B means giving 8 to 9 L of milk and C means giving 6 to 7 L of milk.

Table 5. Zinc homeostasis (ppm) at different levels of milk production in graded buffaloes.

Total Zn Intake (Feed + Water)			Total Zn Outgo (Faeces + Urine + Milk)			Zn Retention			Zn Retention (% of intake)			Gut Absorption of Zn (%)		
A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
481.6	403.0	327.5	251.08	227.8	205.1	230.51	175.17	122.4	47.86	43.46	37.38	57.68	53.04	46.66

Groups A means buffaloes giving more than 10 L of milk, B means giving 8 to 9 L of milk and C means giving 6 to 7 of milk.

offering fodder to buffaloes.

The trend exhibited that as the milk production is decreased, Zn absorption and Zn retention both is decreased (Figure 3). This suggested per unit increase in milk production increases the Zn requirement in more and so as a compensatory mechanism to maintain plasma Zn level, Zn retention and absorption is regulated accordingly (Table 5). This trend indicates higher supplementation of Zn is required in high yielding buffaloes.

Comparative requirement of Zn with respect to milk production was more, hence deficiency of Zn was found to be more in high milk yielding buffaloes (Figure 4). High yielding buffaloes are supplied with more quantity of concentrate which are rich in Zn. However, medium yielding buffaloes were supplied more Zn through fodder, thus the deficiency was found to be almost similar in both high and medium yielding buffaloes (Table 4). Low yielders are provided with more of dry fodder which is low in Zn, thus Zn deficiency was more in low yielders.

Signs of Zn deficiency are non-specific, therefore Zn status should be considered in cases of unexplained reproductive problems (Apgar and Fitizgerald, 1985; Khan *et al*., 2005). Plasma Zn is a reasonable criterion however, values are susceptible to animal stress during sampling and can fluctuate rapidly (Underwood, 1981). According to Conrad (1978) the plasma Zn is rapidly and markedly reduced with severely deficient diets, although concentrations were not greatly influenced by marginally deficient forage Zn as found in this study. Based on soil, forage, feed, water and animal samples analyses, it was concluded that few sample was deficient in Zn, but animal was able to maintain the plasma Zn level to some extent (about 74%). Therefore, a mixture containing Zn should be continually supplemented when forage Zn contents were on borderline levels. Zinc homeostasis is largely regulated by its uptake and loss through the small intestine. Supplementation of $ZnSO_4$ (containing 33% available Zn) is required at the rate of 1.5 gms/day to overcome sub-clinical Zn deficiency.

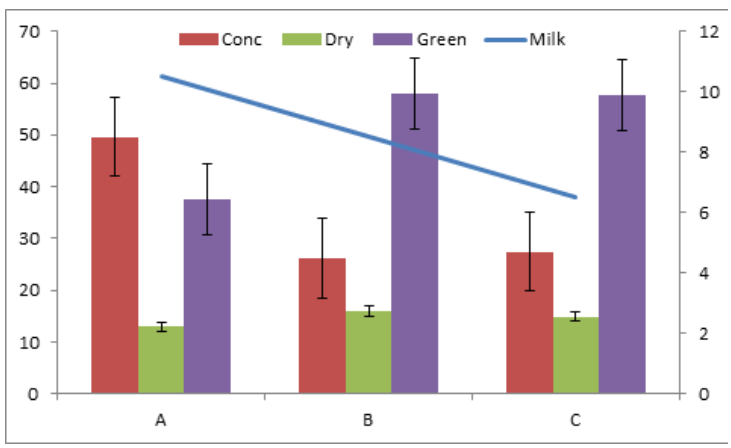

Figure 2. Source of Zn through different feeding resources in different levels of milk yielding buffaloes. Groups A means buffaloes giving more than 10 L of milk, B means giving 8 to 9 L of milk and C means giving 6 to 7 L of milk.

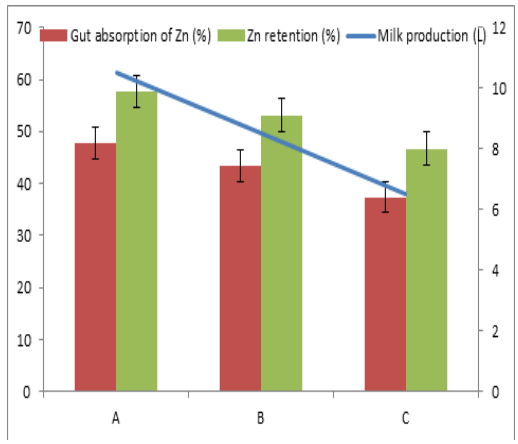

Figure 3. Trend of Zn absorption and retention with respect to milk production groups in buffaloes. Groups A means buffaloes giving more than 10 L of milk, B means giving 8 to 9 L of milk and C means giving 6 to 7 L of milk.

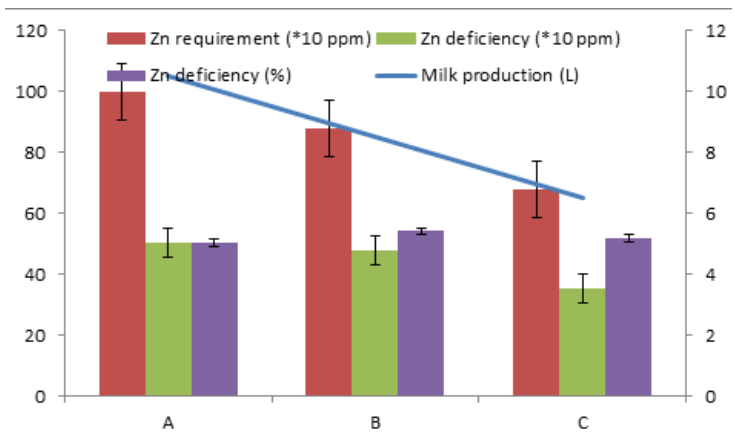

Figure 4. Zinc requirement and deficiency with respect to production level in buffaloes.
Groups A means buffaloes giving more than 10 L of milk, B means giving 8 to 9 L of milk and C means giving 6 to 7 L of milk.

CONCLUSION

After grazing, dry fodder is mostly the feed source for buffaloes giving less than 6 litres of milk per day, making them vulnerable for Zn deficiency. No tree samples were deficient in Zn level which suggested a good scope of offering tree leaves in Zn deficient areas. Low productive buffaloes are scarcely given concentrate making them vulnerable to Zn deficiency. Buffalo faecal samples were high in Zn content which may be contributing immensely to the recycling of Zn in nature through soil and plants. Serum Zn content has a highly significant correlation with milk and faecal Zn content which suggests that even if we are not taking blood from buffaloes, which is very difficult under field conditions as well as its very difficult to convince farmers for pricking of their animals for blood collection, milk or faecal collection (non-pricking) can suggest Zn status of animal. Almost 50% of Zn intake is going out of the body of buffaloes through faeces, urine and milk which suggests need to tap the run off Zn from body of buffalo in means of faeces, urine and milk.

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REFERENCES

Apgar, J. and J.A. Fitzgerald. 1985. Effect on the ewe and lamb of low Zn intake throughout pregnancy. *J. Anim. Sci*., **60**: 1530-1538.

Arora, S.P. 1981. Zinc and vitamin A relationship in metabolism. *In* Gawthorne, J.M. (ed). *TEMA-4*, Perth, Australia: Springer-Verlag, Berlin, New York, USA. 572p.

Bali, S.K., R. Kumar, H.S. Hundal, K. Singh and B. Singh. 2010. GIS-aided mapping of DTPA extractable zinc and soil characteristics in the state of Punjab. *Journal of the Indian Society of Soil Science*, **58**: 189-199.

Banik, S., P.K. Pankaj, S. Naskar, P.K. Malik, R. Bhatta, J. Takahashi, R.A. Kohn and C.S. Prasad. 2015. Climate change: impacts on livestock diversity in tropical countries, p. 162-182. *In* Malik, P.K., R. Bhatta, J. Takahashi, R.A. Kohn and C.S. Prasad. (eds). *Livestock Production and Climate Change*, CPI Group, UK.

Beeson, K.C. and G. Matrone. 1976. *The Soil Factor in Nutrition: Animal and Human.* Marcel Dekker, New York, USA. 152p.

Conrad, J.H. 1978. Soil, plant and animal tissue as predictors of the mineral status of ruminants, *In* Conrad, J.H. and L.R. McDowell. *Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants*. University of Florida, Gainesville, USA.

Cox, F.R. 1973. Micronutrients, . *In A Review of Soil research in tropical Latin America*. North Carolina Agricultural Experiment Station Cottage, Raleigh, USA.

Fick, K.R., L.R. McDowell, P.H. Miles, N.S. Wilkinson, J.D. Funk and J.H. Conrad. 1979. *Methods of Mineral Analysis for Plant and Animal Tissues*, 2nd ed. Department of Animal Sciences, University Florida, Gainesville, USA.

Fujihara, T., T. Matsui, S. Hayashi, A.Y. Robles, A.B. Serra, L.C. Cruz and H. Shimizu.

1992. Mineral Status of Grazing Philippine goats. II. The nutrition of selenium, copper and zinc of goats in Luzon Island. *Asian Austral. J. Anim. Sci*., **5**: 389-395.

Garg, M.R., B.M. Bhanderi and P.L. Sherasia. 2005. Assessment of Adequacy of macro and micro mineral content of feedstuffs for dairy animals in semi-arid zone of Rajasthan. *Animal Nutrition and Feed Technology*, **5**: 8-20.

Hayashi, M., Y. Ogura, I. Koike, N. Yabe, R. Mudigdo and A. Paranginangin. 1985. Mineral concentrations in serum of cattle and buffalo and some herbages collected from pastures around Medan in Indonesia. *Bull. Natl. Anim. Hlth.*, **88**: 35-41.

Kabata-Pendias, A. and H. Pendias. 1992. *Trace Elements in Soils and Plants*. CRC Press Inc., Boca Raton, Florida, USA.

Katyal, J.C. and R.K. Rattan. 2003. Secondary and micronutrients: Research gaps and future needs. *Fertiliser News*, **48**: 9-14, 17-20.

Khan, Z.I., A. Hussain, M. Ashraf and L.R. McDowell. 2006. Mineral status of soils and forages in South Western Punjab-Pakistan: Micro-minerals. Asian-Aust. *J. Anim. Sci*., **19**: 1139-1147.

Khan, Z.I., A. Hussain, M. Ashraf, E.E. Valeem, M.Y. Ashraf, L.R. McDowell, M.S. Akhtar and M.A. Mirza. 2005. Effect of seasonal variation on the zinc content of soil, forage, water, feed, and small ruminants grazing the native and improved pasture during different seasons in the semiarid region of Pakistan. *Int. J. Biol. Biotech*., **2**(2): 465-474.

Kincaid, R.L. 1999. Assessment of trace mineral status of ruminants: A review. *In Proceedings of the American Society of Animal Science*, Department of Animal Sciences, Washington State University, Pullman, USA.

Koh, T.S. and G.T. Judson. 1986. Trace elements in sheep grazing near a lead-zinc smelting complex at port pirie, South Australia. *B. Environ. Contam. Tox*., **37**: 87-95.

Kumaresan, A., K.M. Bujarbaruah, K.A. Pathak, Brajendra and T. Ramesh. 2010. Soil-plant-animal continuum in relation to macro and micro mineral status of dairy cattle in subtropical hill agro ecosystem. *Trop. Anim. Health Prod*., **42**(4): 569-577.

McDowell, L.R and J.D. Arthington. 2005. *Minerals for Grazing Ruminants in Tropical Regimes*, 4th ed. University of Florida, Ginessville, USA. p. 1-86.

McDowell, L.R. 1985. *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press New York, USA. 443p.

McDowell, L.R., J.H. Conard, G.L. Ellis and J.K. Loosli. 1983. *Minerals for Grazing Ruminants in Tropical Regions*. Animal Science Department, Centre for Tropical Agriculture, University of Florida, Florida, USA. 89p.

Narwal, R.P., R.R. Dahiya and R.S. Malik. 2013. Pollutant elements in soil-plant-animal system in India and future thrust areas. *European Chemical Bulletin*, **2**(1): 38-45.

Neathery, M.W., N.A. Crowe, W.J. Miller, C.T. Crowe, J.L. Varnado and D.M. Blackmon. 1990. Influence of dietary aluminum and phosphorus on zinc metabolism in dairy calves. *J. Anim. Sci.*, **68**: 4326-4333.

Pankaj, P.K. and D.B.V. Ramana. 2013. Climate resilient small ruminant production in drylands, p. 69-74. *In* Sahoo, A., K. Davendra and S.M.K. Naqvi. (eds). *Climate Resilient Small Ruminant Production*,

National Initiative on Climate Resilient Agriculture (NICRA) and Central Sheep and Wool Research Institute (CSWRI), Avikanagar, Rajasthan, India.

Pankaj, P.K., D.B.V. Ramana, R. Pourouchottamane and S. Naskar. 2013a. Livestock management under changing climate scenario in India. *World Journal of Veterinary Science*, **1**(1): 25-32.

Pankaj, P.K., V. Venkatasubramanian, R. Pourouchottamane, D.B.V. Ramana and A. Mishra. 2013b. Problems of buffalo reproduction: Identification and ways to ameliorate infertility. *Vet. Prac.*, **14**(1): 192-197.

Ramana, J.V., C.S. Prasad and S.K. 2000. Mineral profile of soil, feeds fodders and blood plasma in southern transition zone of Karnataka. *Indian Journal of Animal Nutrition*, **17**(3): 179-183.

Rego, T.J., K.L. Sahrawat, S.P. Wani and G. Pardhasaradhi. 2007. Widespread deficiencies of sulphur, boron and zinc in Indian semi arid tropical soils: On farm crop responses. *J. Plant Nutr.*, **30**: 1569-1583.

Reid, R.L. and D.J. Horvath. 1980. Soil chemistry and mineral problems in farm livestock: A review. *Anim. Feed Sci. Tech.*, **5**: 95-167.

Rhue, R.D. and G. Kidder. 1983. *Analytical Procedures used by the IFAS Extension Soil Laboratory and the Interpretation of Results*. Soil Science Department, University of Florida, Gainesville, USA.

Shukla, A.K., B.S. Dwivedi, V.K. Singh and M.S. Gill. 2009. Macro role of micro nutrients. *Indian Journal of Fertilisers*, **5**(5): 11-30.

Singh, M.V. 2009. Micronutrient nutritional problems in soils of India and improvement for human and animal health. *Indian Journal of Fertilisers*, **5**: 11-16.

Snedecor, G.W. and W.G. Cochran. 1989. *Statistical Methods*, 8th ed. Iowa State University Press, USA.

Srinivasarao, Ch., K.P.R. Vittal, P.N. Gajbhiye, K. Sumantha and K.L. Sharma. 2008. Distribution of micronutrient in soil in rainfed production systems of India. *Indian Journal of Dryland Agricultural Research and Development*, **23**(1): 29-35.

Srinivasarao, Ch., S.P. Wani, K.L. Sahrawat and B.K. Rajasekhara. 2009. Nutrient management strategies in participatory watersheds. *Indian Journal of Fertilisers*, **5**: 113-128.

Srinivasarao, Ch, B. Venkateswarlu, R. Lal, A.K. Singh and S. Kundu. 2013. Sustainable manangement of soils of dryland ecosysytems of India for enhancing agronomic productivity and sequestering carbon. *Adv. Agron.*, **121**: 254-329.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics*. *A Biometrical Approach*, 2nd ed. Mcgraw Hill Book Co., New York, USA.

Tejada, R., L.R. McDowell, F.G. Martin and J.H. Conrad. 1985. Mineral element analyses of various tropical forages in Guatemala and their relationship to soil concentrations. *Nutritional Report. International.*, **32**: 313-323.

Tejada, R., L.R. McDowell, F.G. Martin and J.H. Conrad. 1987. Evaluation of cattle trace mineral status in specific regions of Guatemala. *Trop. Agr.*, **64**: 55-60.

Tiffany, M.E., L.R. McDowell, G.A. O'Connor, H. Nguyen, F.G. Martin, N.S. Wilkinson and N.A. Katzowitz. 2001. Effects of residual and reapplied biosolids on forage and soil

concentrations over a grazing season in north Florida. II. Microminerals. *Commun. Soil Sci. Plant*, **32**: 2211-2226.

Underwood, E.J. 1981. *The Mineral Nutrition of Livestock*. Commonwealth Agricultural Bureaux, London, UK. p. 223-225.

Vijchulata, P., S. Chipadpanich and L.R. McDowell. 1983. Mineral status of cattle raised in the villages of central Thailand. *Tropic. Anim. Prod*., **8**: 131-137.