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Effect of Organic Sources on Quality Of Kodo Millet (*Paspalum Scorbiculatum* L.) And Soil Properties Under Organic Condition

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ABSTRACT

A field experiment was conducted during the Kharif season of 2023 at the College Agronomy Farm, B.A. College of Agriculture, Anand Agricultural University, Anand. The study aimed to evaluate the impact of various organic sources on the quality of Kodo millet and the associated soil properties under organic farming conditions. The trial site's soil had a loamy sand texture, was medium in accessible potassium and phosphorus, and had low levels of organic carbon and available nitrogen. The experiment was conducted in a Randomized Complete Block Design with three replications and ten treatments. Experiment results showed that application of 75 % N through castor cake fb soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS reported higher protein content, nitrogen and phosphorus content and uptake by grain and straw, phosphorus content and zinc uptake by straw, calcium and iron uptake by grain and straw. Iron and potassium content in grain and zinc content in straw was significantly higher where 100 % nitrogen was applied through vermicompost. Nitrogen content in straw was observed higher in treatment 75 % N through neem cake fb soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS. After harvest soil nutrient status like nitrogen, phosphorus and potassium as well as soil microbial population were significantly higher by application of 75 % N through castor cake fb soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS. The application of various organic treatments had no significant effect on the calcium content in grain and straw, iron content in straw, and post-harvest soil parameters such as electrical conductivity (EC), pH, and organic carbon.

Keywords: *Bio NPK consortium, Calcium, Castor cake, Kodo millet, Neem cake, Protein content, Zinc, Iron and Vermicompost,*

INTRODUCTON

Millets, once a staple crop in India, have faced neglect and marginalization, particularly following the Green Revolution, which emphasized high-yield wheat and rice cultivation. However, as concerns about lifestyle diseases and the downsides of a heavily refined diet grow, millets are regaining attention for their incredible nutritional benefits. Among these, Kodo millet stands out as a nutrient-dense option, offering an excellent alternative to traditional grains like wheat and rice. Each 100g of Kodo millet contains the following nutrients: energy (302 kcal), protein (8.03 g), carbohydrate (69.9 g), crude fibre (8.5 mg), calcium (22.0 mg) and iron (9.9 mg) [2].

Kodo millet (*Paspalum Scorbiculatum* L.) is found worldwide in moist tropical and subtropical environments. It is indigenous cereal of India, mostly grown in Madhya Pradesh, Tamil Nadu, Maharashtra, Karnataka and some parts of Andhra Pradesh. It is also known as Kodo (Hindi), Varagu (Tamil), Arika (Telugu), Kodra (Gujarati, Marathi and Punjab) [6].

Anthropogenic factors, including inappropriate land use practices, monocropping, nutrient mining, and insufficient nutrient replenishment, have exacerbated the problem. Nutritional insecurity remains a significant health challenge in India, affecting the well-being of a large portion of the population. This issue can be addressed through the inclusion of a diverse range of foods that provide essential nutrients critical for human health. Currently, a majority of the population relies on a cereal-based diet and refined food products as their primary source of energy. While such diets are calorie-dense, they lack several key nutrients, including crude fiber, proteins, minerals, antioxidants, and vitamins. This nutritional imbalance contributes to widespread deficiencies and exacerbates the problem of nutritional insecurity [7]. Growing different millets under organic farming has great potential to improve the nutritional value of foods/meals and its product. Organic farming offers a sustainable alternative that aligns with the principles of environmental stewardship and human health. By choosing organic produce and food products, consumers can reduce their exposure to harmful chemicals and support farming practices that promote ecological balance. As the demand for organic food continues to grow, it underscores a collective desire for healthier, safer, and more environmentally friendly food systems. The transition to organic farming is not just a trend, it is a vital step toward securing a healthier future for both people and the planet. Various methods that can enhance soil fertility organically, include using bio-fertilizers, organic manures, etc. [4]. Finally organic agriculture is a production system that sustain human and soil health as well as ecosystems.

FYM acts as a soil conditioner and also provides all the macro and micronutrients. It contains approximately 0.3% N, 0.15% P_2O_5, and 0.3% K_2O [16]. It also improves the physico-chemical properties of the soil and stimulate microbial activity in the soil. Compared to FYM, castor cake is a quick-acting organic manure that has a higher percentage of major plant nutrients *viz.*, nitrogen (3.95%), phosphorus (1.58%) and potash (1.20%) [10].

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Vermicompost is one of the potential sources due to readily available plant nutrients and substances that promote growth, like auxins and gibberellins. It contains a variety of beneficial microorganisms, including nitrogen-fixing, P-solubilizing, and cellulose decomposing organisms and about 1.5% N, 2% P_2O_5, and 0.5% K_2O [16]. Neem cake is suggested for use in organic farming, because neem cake is easily biodegradable and environmentally friendly. It contains about 5.2-5.3% N, 1.0-1.1% P_2O_5, 1.4-1.5% K_2O [16]. The bio NPK consortium is a mixer of bacterial cultures *viz.*, *Azotobacter chroococcum, Azospirillum lipoferum* and *Bacillus* spp. For crops, it is primarily used as a biopesticide and biofertilizer. In addition to promoting better plant growth, it's beneficial microorganisms can preserve the soil's productivity and environmental health when used in place of chemical fertilizers.

In light of the growing recognition of organic farming's potential to enhance nutritional value and environmental sustainability, the present study was undertaken to evaluate the impact of various organic inputs on the quality of Kodo millet (*Paspalum scrobiculatum*) and the associated soil properties under organic farming conditions.

MATERIALS AND METHODS

Location and description of the experiment

The experiment was carried out at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during *kharif* season of the year 2023, The area has a semi-arid, subt ropical climate with hot, dry summer, fairly cool and dry winter and a monsoon that is rather humid which begins by the middle of the June and ends by the middle of the September. The experiment soil is loamy sand texture and has medium in accessible potassium (239 kg ha^{-1}) and phosphorus (45 kg ha^{-1}) and had low levels of organic carbon (0.39%) and available nitrogen (188 kg ha^{-1}). The initial soil microbial count was 7.2 $\times 10^4$ cfu/g.

The sowing of Kodo millet var. GK 4 (Gujarat Kodra 4) was done in June 2023 by drilling method of sowing with 22.5 cm spacing and 12-15 kg/ha seed rate. Standard agronomical practices follow during the crop growth period, including one inter culturing and two hand weeding at the initial growth phase.

Treatments and experimental design

Experiment was laid out in Randomized complete Block Design (RCBD) with three replications with ten treatments, *viz.,* Absolute control (T_1), seed treatment of Bio NPK consortium (5.0 ml/kg) *fb* soil drenching at 30 and 45 DAS (1.0 L/ha) (T_2), 100 % N through FYM (T_3), 100 % N through vermicompost (T_4), 100 % N through castor cake (T_5), 100 % N through neem cake (T_6), 75 % N through FYM *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS (T_7), 75 % N through vermicompost *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS (T_8), 75 % N through castor cake *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS (T_9), 75 % N through neem cake *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS (T_{10}), (Seed treatment of Bio NPK consortium @ 5 ml/kg was given in treatments T_7, T_8, T_9 and T_{10}). The RDF of kodo millet was 40:20:00 NPK kg/ha. All the organic manures were incorporated 15 days before sowing in respective treatment.

Experimental observations

All the parameters underwent statistical analysis and interpretation according to the procedure described by Cochran and Cox (1967).

The experimental data were analyzed using analysis of variance (ANOVA) under a Randomized Complete Block Design (RCBD). This approach allowed for the comparison of treatment means and facilitated the drawing scientifically valid conclusions regarding the statistical significance of differences between treatments.

RESULT AND DISCUSSION

Quality and nutrient content

Millets, often dismissed as "coarse grains," are small-seeded cereals that have been cultivated for thousands of years. These grains include sorghum (jowar), pearl millet (bajra), finger millet (ragi) and Kodo millet, which are highly regarded for their nutritional content and their minimal environmental footprint. Millets are a major energy source and staple food for people living in the dry and arid regions of the world [14].

Various treatments of organic sources influenced protein content in kodo millet grain (Table 1 and 2). Seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through castor cake *fb* soil application Bio NPK consortium @ 1 L ha^{-1} at 30 and 45 DAS (T_9) recorded higher protein content (8.34%) of grain but it was statistically par with treatment T_4, T_5, T_7, T_8 and T_{10}. Significantly lower protein content in grain recorded from treatments T_2 [Seed treatment of Bio NPK consortium (5.0 ml kg^{-1}) *fb* soil drenching at 30 and 45 DAS (1.0 L ha^{-1})] and T_1 (Absolute control), 5.42 % and 5.70 % respectively, Treatment T_7 reported 49.95% higher iron content than absolute control treatment T_1. Application of organic manure, bio fertilizer through soil application and seed treatment reported higher protein content in kodo millet grain, it might be due to utilization of castor cake, known for its lower C:N ratio, accelerates mineralization processes, leading to increased nitrogen availability. This availability is essential for protein synthesis in plants, as nitrogen serves as a fundamental element in amino acids, which are the foundational components of proteins. Addition of organic sources enhanced microbial activity and the fixation of atmospheric nitrogen. These microbes produce various growth-promoting substances that speed up physiological processes such as carbohydrate and protein synthesis, by this way organic manures and bio-fertilizers significantly improve protein content in crops [3] & [1]. Response of different organic manure treatments on iron and zinc content of grain were found significant. An application of 100% nitrogen through vermicompost (T_4) resulted in higher iron content (98.54 mg kg^{-1}) in grain, compared to the absolute control (T_1) which had lower iron content (47.06 mg kg^{-1}). The study found that the response of different organic sources to the iron content in straw was non-significant (Table 1). Significantly higher iron content observed with the application of vermicompost might be due to the quick decomposition of organic manures due to lower C:N ratio, which enhanced availability and subsequently uptake and content of nutrients [13]. While, higher Zn content (22.75 and 29.18 mg kg^{-1}) in grain and straw, respectively observed with treatment T_8 [Seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through vermicompost *fb* soil drenching of Bio NPK consortium (1.0 L ha^{-1}) at 30 and 45 DAS] and T_4 (100 % N through vermicompost (T_4), respectively. Whereas the absolute control (T_1) showed the lowest Zn content (11.67 and 5.58 mg kg^{-1}) in grain and straw, respectively. In grain, T_8 reported 48.70% higher zinc content in grain than T_1. Significantly higher Zn observed with the application of vermicompost along with Bio NPK consortium may be due to the vermicompost had higher zinc content compared to other types of manure used, potentially increased availability, uptake, and content [11].

Nutrient Content

Millets are ancient grains that are naturally gluten-free and packed with essential nutrients, making them an excellent choice for maintaining a healthy lifestyle. They are rich in dietary fiber, which aids digestion, supports gut health, and helps manage weight by promoting a feeling of fullness. In addition to their high fiber content, millets are abundant in vital micronutrients such as calcium, iron, phosphorus, and magnesium. These nutrients are crucial for maintaining bone health, supporting oxygen transport in the blood, and ensuring overall cellular function.

Significant increase in nutrient content like nitrogen, phosphorus, potassium and calcium in grain and straw (Table 2). Significantly higher nitrogen content in grain and straw (1.33 and 0.78%) was reported in treatment T_9 (Seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through castor cake *fb* soil drenching of Bio NPK consortium (1.0 L ha^{-1}) at 30 and 45 DAS) and T_{10} (Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through neem cake *fb* soil drenching of Bio NPK consortium (1.0 L ha^{-1}) at 30 and 45 DAS), respectively. Treatment T_9 (Seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through castor cake *fb* soil drenching of Bio NPK consortium (1.0 L ha^{-1}) at 30 and 45 DAS) reported significantly higher phosphorus content in grain and straw (1.33 and 0.247 %, respectively) and treatment T_4 reported higher potassium content in grain and straw (0.13 and 2.42%, respectively) compared to Absolute control (T_1). The significantly higher nutrient content in grain and straw with application of organic manures such as castor cake, combined with biofertilizers, accelerates the growth of soil microorganisms. This, in turn, increases enzymatic activity, facilitates mineralization and solubilization of both native and applied nutrients, making them more accessible for plant uptake and raising nutrients content [17].

Applying vermicompost resulted in a significant increase in nutrient content, which may have been caused by quicker decomposition of organic manures, which was aided by a lower C:N ratio. This accelerated decomposition increased nutrient availability, which in turn increased nutrient content [13 & 15]. Effect of different organic manure treatments on Ca content in grain and straw was found non-significant.

Nutrient Uptake

Nutrient uptake by grain and straw was significantly influenced due to various organic sources in Kodo millet (Table 3). Seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through castor cake *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS (T_9) recorded significantly higher uptake of nitrogen (37.30 and 56.09 kg ha^{-1}), phosphorus (11.74 and 18.38 kg ha^{-1}), calcium (22.06 and 28.69 kg ha^{-1}) and iron (259.46 and 198.49 g ha^{-1}) by grain and straw, respectively. Seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through vermicompost *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS) [T_8] reported significantly higher potassium (3.34 and 163.06 kg ha^{-1}) and zinc (63.43 and 198.49 kg ha^{-1}) uptake by grain and straw, respectively. Increasing potassium and zinc uptake by grain and straw might be due to the rapid mineralization of castor cake and increased microbial activity from the Bio NPK consortium likely contributed to the significant increase in nutrient uptake seen when nitrogen was applied through castor cake and the Bio NPK consortium [5 & 13].

The considerable increase in potassium uptake observed with the application of vermicompost combined with the Bio NPK consortium might be due to high potassium content in vermicompost and improved potassium availability facilitated by increased microbial activity [9].

Soil chemical and biological properties

Chemical properties

Treatments of nitrogen management through organic sources failed to influence soil pH, electrical conductivity (dS m^{-1}) and organic carbon content (%) in the soil significantly (Table 4). A neutral pH range (7.36 to 7.67) and organic carbon content ranging from 0.49 % to 0.55 % was observed after the harvest of the crop. Significantly higher amount of available nitrogen (240 kg ha^{-1}), available phosphorus (61 kg ha^{-1}) and available potassium (281 kg ha^{-1}) was observed with seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % recommended nitrogen through castor cake *fb* soil drenching of Bio NPK consortium @ 1.0 L/ha at 30 and 45 DAS (T_9). The application of organic nutrient sources and the Bio NPK consortium together allowed more atmospheric nitrogen to be fixed into the soil, which may have contributed to the increase in available nitrogen. Additionally, the Bio NPK consortium inoculation increased the soil's nitrate reductase and nitrogenase enzyme activity, which stimulates biological nitrogen fixation by Rhizobium bacteria and makes it easier for soil nitrogen to mineralize. As a result, there was a significant increase in the availability of nitrogen and increased microbial activity also enhanced efficiency of applied nutrients *i.e.,* phosphorus in the soil [12]. While, higher amount of available potash in soil after harvest might be due to the decrease in fixation of released potassium that occurs because of the interaction between organic matter and clay, which directly adds potassium to the available potassium pool in the soil, thereby increasing its availability [10].

Biological property

Data presented in Table 4 indicated that significantly higher microbial count (5.0×10^9) was observed with seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through castor cake *fb* soil drenching of Bio NPK consortium @ 1.0 L/ha at 30 and 45 DAS (T_9). It might be due to the Bio NPK consortium along with organic sources highlight the synergistic relationship between these components. The Bio NPK consortium boosts soil microbial activity by incorporating beneficial microorganisms like potassium-mobilizing, phosphate-solubilizing, and nitrogen-fixing bacteria. These beneficial microbes grow and multiply when mixed with organic manures, increasing the total microbial counts [12].

Conclusion

On the basis of experiment study, it can be concluded that seed treatment of Bio NPK consortium @ 5 ml kg^{-1} + 75 % N through castor cake *fb* soil drenching of Bio NPK consortium @ 1.0 L/ha at 30 and 45 DAS treatment reported significantly higher nitrogen and phosphorus content (grain and straw), uptake of nitrogen, phosphorus, calcium and zinc and improved soil nutrient status (nitrogen, phosphorus and potassium) as well as soil microbial population. Whereas treatment. Application of 75 % N through vermicompost *fb* soil drenching of Bio NPK consortium (1.0 L/ha) at 30 and 45 DAS noted higher zinc content grain and uptake and potassium content in grain and straw. Potassium content in grain and straw and iron content in grain was reported higher by application of 100% nitrogen through vermicompost.

Post-harvest analysis revealed that soil nutrient status, including parameters such as electrical conductivity (EC), pH, and organic carbon, along with calcium content and its uptake by Kodo millet grain and straw, showed no significant differences.

FUTURE SCOPE OF THE EXPERIMENT

Further research on detailed analysis of specific mechanism of nutrient release, availability and microbial interection associated with various organic amendments in organically grown kodo millet will further enhance its value proposition. Moreover, long term studies are necessary to assess the sustainability aspects, including carbon sequestration and resilience to climate change.

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest in this research work.

Table 1. Effect of treatments on protein and micronutrient content

Treatment	Protein content (%)	Iron content (mg/kg)		Zinc content (mg/kg)	
		Grain	Straw	Grain	Straw
T_1	5.70	47.06	6.78	11.67	5.58
T_2	5.42	70.11	7.04	15.51	6.29
T_3	7.38	60.85	7.05	16.68	7.20
T_4	7.62	98.54	7.11	15.61	29.18
T_5	7.78	82.46	7.25	15.25	7.45
T_6	7.54	65.08	7.28	20.78	7.52
T_7	8.00	94.03	7.08	16.84	12.47
T_8	8.31	75.09	7.83	22.75	12.45
T_9	8.34	92.85	7.64	19.51	26.59
T_{10}	8.05	92.63	7.37	18.66	22.44
S.Em. ±	**0.28**	**3.31**	**0.25**	**0.73**	**0.41**
C.D. (P=0.05)	**0.85**	**7.37**	**NS**	**2.18**	**1.21**
C.V. %	6.66	9.85	5.96	7.32	5.12

Table 2. Effect of treatments on nutrients content in grain and straw

Treatment	Nutrients content in grain				Nutrients content in straw			
	N (%)	P (%)	K (%)	Ca (%)	N (%)	P (%)	K (%)	Ca (%)
T_1	1.14	0.343	0.10	0.69	0.53	0.137	1.45	0.34
T_2	1.16	0.370	0.11	0.70	0.59	0.167	1.61	0.35
T_3	1.18	0.393	0.12	0.71	0.71	0.170	1.63	0.35
T_4	1.22	0.373	0.13	0.71	0.73	0.197	2.42	0.37
T_5	1.24	0.410	0.11	0.71	0.75	0.170	1.86	0.38
T_6	1.21	0.417	0.12	0.71	0.73	0.180	1.94	0.36
T_7	1.28	0.417	0.12	0.71	0.75	0.170	1.77	0.38
T_8	1.33	0.353	0.12	0.72	0.77	0.200	2.31	0.35
T_9	1.33	0.420	0.12	0.79	0.75	0.247	1.75	0.39
T_{10}	1.29	0.417	0.11	0.75	0.78	0.220	1.75	0.38
S.Em. ±	**0.04**	**0.01**	**0.0023**	**0.021**	**0.02**	**0.01**	**0.07**	**0.013**
C.D. (P=0.05)	**0.11**	**0.03**	**0.0068**	**NS**	**0.07**	**0.02**	**0.22**	**NS**
C.V. %	5.39	4.94	3.49	4.97	5.86	5.17	6.93	6.41

Table 3. Effect of treatments on nutrients uptake in grain and straw

Treatment	Nutrients uptake in grain						Nutrients uptake in straw					
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Zn (g ha^{-1})	Fe (g ha^{-1})	N (kg ha-1)	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Zn (g ha^{-1})	Fe (g ha^{-1})
T_1	18.19	5.44	1.54	11.04	18.62	75.29	23.90	6.18	65.70	15.16	30.58	24.95
T_2	19.78	6.34	1.82	11.90	26.57	119.77	28.57	8.00	77.00	16.55	33.68	29.95
T_3	25.87	8.65	2.65	15.39	36.42	134.02	40.25	9.72	92.37	19.92	40.26	40.84
T_4	27.64	8.46	2.87	16.06	35.40	222.49	45.56	12.28	151.05	22.94	44.37	182.39
T_5	29.78	9.80	2.63	16.95	36.95	197.03	46.98	10.72	116.12	23.53	45.31	46.85
T_6	27.34	9.40	2.65	16.05	46.98	147.57	41.47	10.25	109.93	20.38	41.21	42.67
T_7	34.39	11.14	3.22	19.12	45.00	252.13	47.32	10.66	111.11	23.91	44.58	78.32
T_8	37.18	9.84	3.34	19.98	63.43	207.56	54.44	14.15	163.06	24.54	55.44	88.17
T_9	37.30	11.74	3.26	22.06	54.66	259.46	56.09	18.38	130.16	28.69	56.79	198.49
T_{10}	35.97	11.56	3.05	20.98	51.85	253.81	49.00	13.89	110.93	24.05	46.29	141.13
S.Em. ±	**2.38**	**0.60**	**0.17**	**1.20**	**3.30**	**8.65**	**3.60**	**0.97**	**8.53**	**1.52**	**3.18**	**7.87**
C.D. (P=0.05)	**7.06**	**1.78**	**0.51**	**3.57**	**9.81**	**25.71**	**10.70**	**2.87**	**25.35**	**4.51**	**9.46**	**23.38**
C.V. %	**14.03**	**11.26**	**11.06**	**12.28**	**13.76**	**8.02**	**14.39**	**14.65**	**13.11**	**11.98**	**12.58**	**15.60**

Table 4. Effects of treatments on soil chemical and biological properties

Treatment	Soil chemical proportions						Soil microbial count (*cfu/g*)	
	EC (dS m^{-1})	pH	OC (%)	N	P_2O_5	K_2O	Log transformed value	Original value
				(kg ha^{-1})				
T_1	0.14	7.67	0.49	170	41	228	5.47	(3.4×10^5)
T_2	0.13	7.56	0.51	192	48	246	9.79	(6.3×10^7)
T_3	0.14	7.36	0.55	203	47	256	7.53	(3.4×10^7)
T_4	0.12	7.56	0.53	220	51	265	7.51	(3.3×10^7)
T_5	0.13	7.51	0.54	233	56	276	7.17	(1.6×10^7)
T_6	0.14	7.46	0.53	229	53	269	6.97	(9.5×10^6)
T_7	0.13	7.46	0.52	206	58	259	7.49	(3.1×10^9)
T_8	0.14	7.58	0.51	225	58	266	9.56	(3.6×10^9)
T_9	0.14	7.51	0.50	240	61	281	9.61	(5.0×10^9)
T_{10}	0.13	7.43	0.52	232	59	278	9.62	(4.1×10^9)
S.Em. ±	**0.0058**	**0.25**	**0.013**	**5.07**	**1.72**	**4.69**	**0.10**	
C.D. (P=0.05)	**NS**	**NS**	**NS**	**15.05**	**5.11**	**13.95**	**0.30**	
C.V. %	7.50	5.79	4.23	4.08	5.60	3.10	2.19	

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