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Effect of Different Nitrogen Sources on Grain Yield and Quality Parameters of Scented Rice (*Oryza Sativa* L.)

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Abstract

A field experiment entitled *"Effect of different nitrogen sources on grain yield and quality parameters of scented rice (Oryza sativa L.)"* was conducted at the Agronomy Research Farm, IFTM University, Moradabad (U.P.), during the *Kharif* seasons of 2023 and 2024. The experiment was laid out in a split-plot design with six nitrogen management treatments as main plots, viz., N_0 – Control, N_1 – 100% N through prilled urea, N_2 – 50% N (prilled urea) + two foliar applications of nano urea, N_3 – 50% N (prilled urea) + green manuring + one foliar application of nano urea, N_4 – 75% N (prilled urea) + two foliar applications of nano urea, and N_5 – 75% N (prilled urea) + green manuring + one foliar application of nano urea. Three scented Basmati rice varieties, viz., V_1 – Pusa Basmati 1718, V_2 – Pusa Basmati 1847, and V_3 – Pusa Basmati 1886, were assigned to sub-plots.

The results revealed that grain yield (5.28–5.29 t ha^{-1}), biological yield (11.88–11.97 t ha^{-1}), and stover yield (6.61–6.67 t ha^{-1}) increased significantly with higher levels of nitrogen application. Application of 75% N through prilled urea combined with green manuring and one foliar spray of nano urea (N_5) recorded the highest grain yield, straw yield, and biological yield. Among the varieties, Pusa Basmati 1847 exhibited significantly higher grain protein content and protein yield compared to the other varieties. With respect to nitrogen management, the N_5 treatment produced the maximum protein content (8.1–9.1%) and protein yield (429.93–482.18 kg ha^{-1}). The interaction effect indicated that the combination of V_2 (Pusa Basmati 1847) with N_5 resulted in the highest grain yield, straw yield, and biological yield. Overall, the study suggests that integrated nitrogen management involving reduced chemical nitrogen, green manuring, and nano urea application can enhance productivity and grain quality of scented rice, contributing to sustainable rice production systems.

Keywords: nano urea; nitrogen management; nutrient uptake; grain quality; scented rice

Introduction

The area under scented rice varieties has been steadily increasing due to the expansion of international trade and rising domestic consumption (Singh *et al.*, 2008). Fragrant rice constitutes a premium segment of the global rice market because of its superior aroma and eating quality, thereby commanding higher prices compared to non-aromatic rice (Roy *et al.*, 2020). The characteristic fragrance of scented rice is primarily attributed to the presence of 2-acetyl-1-pyrroline (2AP) in the grains, which is strongly correlated with aroma intensity (Nadaf *et al.*, 2014). However, traditional photosensitive aromatic rice varieties generally exhibit lower yield potential. To address this limitation and meet the demands of farmers and consumers, breeding programs have developed high-yielding, non-photosensitive aromatic rice varieties with improved adaptability (Vanavichit *et al.*, 2018). Globally, several aromatic rice types are well recognized by consumers, including Basmati from India, Jasmine rice from Thailand, Bahra from

Afghanistan, and specialty aromatic rice such as Della, Texmati, and Kasmati from the United States (Singh *et al.*, 2000). Rice plays a pivotal role in Asian livelihoods, providing nearly 70% of daily caloric intake for a large proportion of the population and serving as a major source of income for millions of smallholder farmers and landless laborers (Dawe, 2000). It has profoundly shaped the cultures, diets, and economies of billions of people worldwide and is therefore often referred to as the "grain of life" (Fageria, 2007; Farooq *et al.*, 2009).

In India, food security remains a national priority, as dependence on food imports can compromise foreign policy and economic stability, a challenge commonly faced by low-income food-deficit countries. Rice continues to be the most important cereal crop and the principal staple food in developing countries, particularly across Asia (Redona *et al.*, 2004). Enhancing rice productivity while maintaining grain quality is therefore essential to ensure sustainable food security and farmer profitability.Green manuring is an important agronomic practice for improving soil fertility and sustaining crop productivity. Incorporation of green manure crops has been shown to improve soil physical properties, including soil water retention and aggregate stability (Bhaduri *et al.*, 2018), while also enhancing soil biological properties such as total phospholipid fatty acid (PLFA) content, bacterial biomass, and microbial activity (Chen *et al.*, 2017). Additionally, green manuring in *kharif* rice systems increases the availability of essential nutrients such as nitrogen, phosphorus, potassium, and sulfur (Ehsan *et al.*, 2014). Yield enhancement under green manuring is often attributed to increased panicle weight resulting from a sustained release of nitrogen during the decomposition of organic residues, particularly when dhaincha (*Sesbania aculeata*) is used as a green manure. Green manuring in direct-seeded rice has also been reported to improve crop productivity under excess moisture conditions and to enhance soil health, thereby contributing to long-term sustainability of rice-based production systems (Sahu *et al.*, 2017).

Materials and Methods:

An experiment entitled "Effect of different nitrogen sources on grain yield and quality parameters of scented rice (*Oryza sativa* L.)" was conducted at Research Farm, IFTM University, Moradabad (U.P.) during *Kharif* season 2023 and 2024.The climate of the region is subtropical, characterized by hot summers, cool winters, and an average annual rainfall of about 900–1,000 mm (Fig. 1). The experimental soil was sandy loam, slightly alkaline (pH 7.7), low in organic carbon (0.43%), medium in phosphorus (18.4 kg ha^{-1}) and potassium (208.3 kg ha^{-1}), and had available nitrogen of about 186.7 kg ha^{-1}.The research trial was conducted in split plot design. The treatment consisted of six nitrogen levels viz., N_0- Control, N_1- 100% N (Prilled Urea), N_2- 50% N (Prilled Urea) +2 foliar application of Nano Urea, N_3- 50% N (Prilled Urea) + Green manuring +1 foliar application of Nano Urea, N_4- 75% N (Prilled Urea) + 2 foliar application of Nano Urea and N_5- 75% N (Prilled Urea) + 1 foliar application of Nano Urea + Green manuring and three different scented Basmati varieties (V_1- Pusa Basmati – 1718, V_2- Pusa Basmati - 1847 and V_3- Pusa Basmati – 1886).Twenty-one-day-old seedlings were manually transplanted at 20 × 15 cm distances in main field. Ten days prior to seedling transplantation, green manure (*Sesbania aculeata*) was added. Three equal splits of nitrogen were applied using prilled urea (basal, maximal tillering, and panicle initiation stage). At predetermined intervals, 4% nano urea was sprayed. Potassium (40 kilogram K_2O ha^{-1}) and phosphorus (60 kg P_2O_2 ha^{-1}) were applied consistently. Standard techniques were used to determine the nitrogen content of soil and plant samples. The protein content was then computed by multiplying the nitrogen value by 5.95. ANOVA was used to statistically assess the data for split-plot design (Gomez and Gomez, 1984), and treatment means were compared using Tukey's test at a 5% significance level.

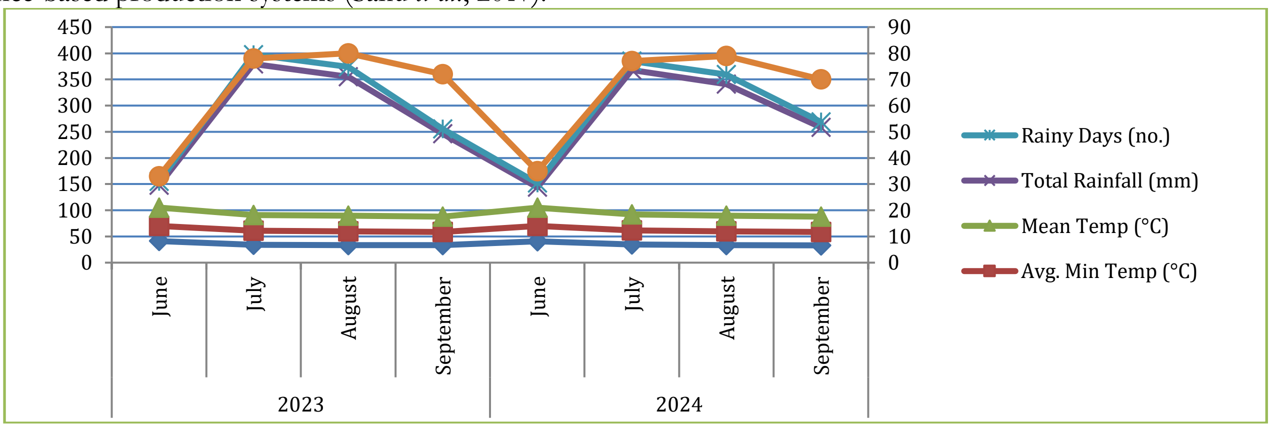

Fig. 1: Monthly weather data for 2023 and 2024

Results and Discussion:

Grain Yield (t ha^{-1})

The data clearly indicated that rice varieties differed significantly in their grain yield during both years of experimentation. Among the varieties, V_2 (*Pusa Basmati 1847*) recorded the highest grain yield (5.62 and 5.64 t ha^{-1} during 2023 and 2024, respectively). During the first year, its performance was statistically at par with V_1 (*Pusa Basmati 1718*) and V_3 (*Pusa Basmati 1886*), whereas in the second year it remained at par only with V_1. The lowest grain yield was recorded with V_3 (*Pusa Basmati 1886*), yielding 4.38 and 4.43 t ha^{-1} during the first and second years, respectively.

Application of different nitrogen management practices exerted a significant influence on grain yield of rice (Table 1). The maximum grain yield was obtained under N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), recording 5.28 and 5.29 t ha^{-1} during 2023 and 2024, respectively. This treatment was statistically at par with N_4 (75% N through prilled urea + two foliar applications of nano urea) and N_1 (100% N through prilled urea) but significantly superior to N_3 (50% N through prilled urea + green manuring + one foliar application of nano urea) during both years of study. The minimum grain yield was consistently observed under the control treatment (N_0), with 4.18 t ha^{-1} in both years.

The interaction effect between varieties and nitrogen levels was also found to be significant. The highest grain yield was recorded under the combination of V_2 (*Pusa Basmati 1847*) with N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), followed by other treatment combinations. In contrast, the lowest grain yield was observed when V_3 (*Pusa Basmati 1886*) was grown under the control treatment (N_0). The interaction trends were consistent across both years of experimentation.

The enhanced grain yield under integrated nitrogen management involving reduced chemical nitrogen, green manuring, and nano urea application may be attributed to improved nitrogen availability, enhanced nutrient use efficiency, and sustained nutrient release throughout the crop growth period. Similar findings were reported by Adhikari and Mishra (2004) and Danish et al. (2025), who observed higher grain yield in aromatic rice varieties with integrated application of prilled urea and organic nutrient sources compared to sole application of chemical fertilizers.

Straw yield (t ha^{-1})

The experimental data revealed that rice varieties significantly influenced straw yield during both years of study. Among the varieties, V_2 (*Pusa Basmati 1847*) recorded the highest straw yield (6.39 and 6.43 t ha^{-1} during 2023 and 2024, respectively). During the first year, its performance was statistically at par with V_1 (*Pusa Basmati 1718*) and V_3 (*Pusa Basmati 1886*); however, in the second year, it remained at par only with V_1. The lowest straw yield was observed in V_3 (*Pusa Basmati 1886*), recording 5.90 and 5.91 t ha^{-1} during the first and second years, respectively.

Different nitrogen management practices exerted a significant effect on straw yield of rice (Table 1). The maximum straw yield was recorded under N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), yielding 6.61 and 6.67 t ha^{-1} during 2023 and 2024, respectively. This treatment was statistically at par with N_4 (75% N through prilled urea + two foliar applications of nano urea) and N_1 (100% N through prilled urea), but significantly superior to N_3 (50% N through prilled urea + green manuring + one foliar application of nano urea) in both years. The minimum straw yield was consistently observed under the control treatment (N_0), with values of 5.32 and 5.29 t ha^{-1} during 2023 and 2024.

The interaction effect between varieties and nitrogen levels was significant. The highest straw yield was obtained from the combination of V_2 (*Pusa Basmati 1847*) with N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), followed by other treatment combinations. In contrast, the lowest straw yield was recorded when V_3 (*Pusa Basmati 1886*) was grown under the control treatment (N_0). The trend of interaction effects remained consistent across both years of experimentation.

The increase in straw yield under higher nitrogen levels and integrated nitrogen management may be attributed to enhanced vegetative growth and improved nitrogen availability throughout the crop growth period. These findings are in agreement with Lakshmanan *et al.* (2005), who reported a significant increase in straw yield of Basmati rice with increasing nitrogen application up to 120 kg N ha^{-1}, whereas grain yield showed a non-significant response beyond 60 kg N ha^{-1}.

Biological yield (t ha^{-1})

The results clearly indicated that rice varieties had a significant influence on biological yield during both years of experimentation. Among the varieties, V_2 (*Pusa Basmati 1847*) recorded the highest biological yield, with values of 12.01 and 12.07 t ha^{-1} during 2023 and 2024, respectively. During the first year, its performance was statistically at par with V_1 (*Pusa Basmati 1718*) and V_3 (*Pusa Basmati 1886*); however, during the second year, it remained at par only with V_1. The lowest biological yield was consistently observed in V_3 (*Pusa Basmati 1886*), producing 10.28 and 10.34 t ha^{-1} during the first and second years, respectively.

Nitrogen management practices exerted a significant effect on biological yield of rice (Table 1). The maximum biological yield was obtained under N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), recording 11.88 and 11.97 t ha^{-1} during 2023 and 2024, respectively. This treatment was statistically at par with N_4 (75% N through prilled urea + two foliar applications of nano urea) and N_1 (100% N through prilled urea), but significantly superior to N_3 (50% N through prilled urea + green manuring + one foliar application of nano urea) in both years. The minimum biological yield was recorded under the control treatment (N_0), with values of 9.50 and 9.47 t ha^{-1} during 2023 and 2024.

The interaction effect between varieties and nitrogen levels was significant. The highest biological yield was recorded under the combination of V_2 (*Pusa Basmati 1847*) with N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), followed by other treatment combinations. In contrast, the lowest biological yield was observed when V_3 (*Pusa Basmati 1886*) was grown under the control treatment (N_0). The interaction trend was consistent across both years of study.

The enhanced biological yield under integrated nitrogen management can be attributed to improved vegetative growth, higher dry matter accumulation, and sustained nitrogen availability throughout the crop growth period. These findings corroborate the results of Malik *et al.* (2014), who reported significant improvement in biological yield and other yield attributes of Basmati rice with higher nitrogen application levels, particularly at 120 kg N ha^{-1}.

Harvest Index (%)

The experimental results indicated that rice varieties significantly influenced biological yield during both years of study. Among the varieties, V_2 (*Pusa Basmati 1847*) recorded the highest biological yield, producing 12.01 and 12.07 t ha^{-1} during 2023 and 2024, respectively. During the first year, its performance was statistically at par with V_1 (*Pusa Basmati 1718*) and V_3 (*Pusa Basmati 1886*), whereas in the second year it remained at par only with V_1. The lowest biological yield was consistently recorded in V_3 (*Pusa Basmati 1886*), with values of 10.28 and 10.34 t ha^{-1} during the first and second years, respectively.

The interaction effect between varieties and nitrogen levels was also significant. The highest biological yield was recorded under the combination of V_2 (*Pusa Basmati 1847*) with N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), followed by other treatment combinations. In contrast, the lowest biological yield was obtained when V_3 (*Pusa Basmati 1886*) was grown under the control treatment (N_0). The interaction trends were consistent across both years of experimentation.

The enhanced biological yield under integrated nitrogen management may be attributed to increased biomass accumulation resulting from improved nitrogen availability and prolonged nutrient release throughout the crop growth period. These findings are in agreement with Malik *et al.* (2014), who reported significant improvements in growth parameters, straw yield, biological yield, and grain yield of Basmati rice with higher nitrogen application levels, particularly at 120 kg N ha^{-1}.

Protein (%)

The experimental data revealed that rice varieties significantly influenced grain protein content during both years of study. Among the varieties, V_2 (*Pusa Basmati 1847*) recorded the highest protein content, with values of 7.8 and 8.5% during 2023 and 2024, respectively. During the first year, its performance was statistically at par with V_1 (*Pusa Basmati 1718*) and V_3 (*Pusa Basmati 1886*); however, during the second year it remained at par only with V_1. The lowest protein content was observed in V_3 (*Pusa Basmati 1886*), recording 7.2 and 7.8% during the first and second years, respectively.

Nitrogen management practices had a significant effect on grain protein content (Table 1). The maximum protein content was obtained under N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), recording 8.1 and 9.1% during 2023 and 2024, respectively. This treatment was statistically at par with N_4 (75% N through prilled urea + two foliar applications of nano urea) and N_1 (100% N through prilled urea), but significantly superior to N_3 (50% N through prilled urea + green manuring + one foliar application of nano urea) during both years. The minimum protein content was consistently recorded under the control treatment (N_0), with values of 6.3 and 5.5% during 2023 and 2024.

The interaction effect between varieties and nitrogen levels was significant. The highest protein content was recorded under the combination of V_2 (*Pusa Basmati 1847*) with N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), followed by other treatment combinations. In contrast, the lowest protein content was observed when V_3 (*Pusa Basmati 1886*) was grown under the control treatment (N_0). The interaction trends remained consistent across both years of experimentation.

The improvement in protein content with integrated nitrogen management may be attributed to enhanced nitrogen uptake and assimilation, leading to increased synthesis of storage proteins in rice grains. The present findings partially align with Kumar and Kureel (2017), who reported that while nitrogen application significantly influenced yield parameters, grain quality traits including protein content were not markedly affected beyond certain nitrogen levels in scented rice.

Protein Yield (kg ha^{-1})

The results indicated that rice varieties differed significantly in protein yield during both years of experimentation. Among the varieties, V_2 (*Pusa Basmati 1847*) recorded the highest protein yield, producing 440.24 and 481.91 kg ha^{-1} during 2023 and 2024, respectively. During the first year, its performance was statistically at par with V_1 (*Pusa Basmati 1718*) and V_3 (*Pusa Basmati 1886*); however, during the second year it remained at par only with V_1. The lowest protein yield was consistently observed in V_3 (*Pusa Basmati 1886*), recording 318.35 and 350.47 kg ha^{-1} during the first and second years, respectively.

Different nitrogen management practices exerted a significant effect on protein yield of rice (Table 1). The maximum protein yield was obtained under N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), recording 429.93 and 482.18 kg ha^{-1} during 2023 and 2024, respectively. This treatment was statistically at par with N_4 (75% N through prilled urea + two foliar applications of nano urea) and N_1 (100% N through prilled urea), but significantly superior to N_3 (50% N through prilled urea + green manuring + one foliar application of nano urea) during both years. The minimum protein yield was consistently recorded under the control treatment (N_0), with values of 266.99 and 235.33 kg ha^{-1} during 2023 and 2024.

The interaction effect between varieties and nitrogen levels was significant. The highest protein yield was obtained under the combination of V_2 (*Pusa Basmati 1847*) with N_5 (75% N through prilled urea + one foliar application of nano urea + green manuring), followed by other treatment combinations. In contrast, the lowest protein yield was recorded when V_3 (*Pusa Basmati 1886*) was grown under the control treatment (N_0). The interaction trends were consistent across both years of experimentation.

The enhancement in protein yield under integrated nitrogen management can be attributed to the combined effect of increased grain yield and higher protein concentration resulting from improved nitrogen availability and uptake. These findings are in agreement with Devi *et al.* (2012), who reported significant improvement in protein yield and other quality attributes of scented rice with increasing nitrogen levels, with superior quality observed at optimal nitrogen application rates.

Conclusion

The study demonstrated that varietal choice and integrated nitrogen management significantly influenced yield and quality of scented rice. Among the tested varieties, Pusa Basmati 1847 consistently recorded superior grain yield, biological yield, and protein yield during both years, indicating better adaptability and nitrogen use efficiency. Integrated nitrogen application, particularly 75% nitrogen through prilled urea combined with green manuring and one foliar spray of nano urea, produced yields and protein content comparable to or higher than 100% inorganic nitrogen alone. The significant interaction between variety and nitrogen management further revealed that Pusa Basmati 1847 under integrated nitrogen management was the most productive and quality-enhancing combination. Overall, partial substitution of chemical nitrogen with green manuring and nano urea proved to be an effective and sustainable strategy for improving productivity, grain quality, and nutrient use efficiency in scented rice cultivation.

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Table 1. Effect of different nitrogen levels on Grain yield (t ha^{-1}), Straw yield (t ha^{-1}), Biological yield (t ha^{-1}) and Harvest Index (%) of scented rice.

Treatments	**Yields**							
	Grain yield (t ha^{-1})		**Straw yield (t ha^{-1})**		**Biological yield (t ha^{-1})**		**Harvest Index (%)**	
	2023	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Varieties (Main plot)								
V_1 - Pusa Basmati 1718	4.58	4.63	6.11	6.15	10.69	10.78	42.8	42.9
V_2 - Pusa Basmati 1847	5.62	5.64	6.39	6.43	12.01	12.07	46.8	46.7
V_3 - Pusa Basmati 1886	4.38	4.43	5.90	5.91	10.28	10.34	42.5	42.8
S Em±	0.04	0.06	0.04	0.05	0.08	0.10	0.11	0.23
CD (P=0.05)	0.16	0.23	0.16	0.20	0.31	0.39	0.45	0.91
Nitrogen levels (Sub-plot)								
N_0 - Control	4.18	4.18	5.32	5.29	9.50	9.47	43.8	43.9
N_1 - 100% N (Prilled Urea)	5.08	5.10	6.35	6.42	11.43	11.52	44.3	44.2
N_2 - 50% N (Prilled Urea) +2 foliar application of Nano Urea	4.70	4.81	5.97	5.97	10.67	10.78	43.9	44.5
N_3 - 50% N (Prilled Urea) + Green manuring +1 foliar application of Nano Urea	4.80	4.84	6.08	6.13	10.88	10.97	44.0	43.9

N_4 - 75% N (Prilled Urea) + 2 foliar application of Nano Urea	5.12	5.18	6.48	6.49	11.61	11.68	44.0	44.3
N_5 - 75% N (Prilled Urea) + 1 foliar application of Nano Urea + Green manuring	5.28	5.29	6.61	6.67	11.88	11.97	44.3	44.1
S Em±	0.05	0.06	0.07	0.07	0.12	0.12	0.15	0.20
CD (P=0.05)	0.16	0.16	0.21	0.20	0.35	0.34	NS	NS

Table: 2 Effect of different nitrogen levels on Protein (%), and Protein yield (kg ha^{-1}) of scented rice.

Treatments	**Protein (%)**		**Protein yield (kg ha^{-1})**	
	2023	**2024**	**2023**	**2024**
Varieties (Main plot)				
V_1 - Pusa Basmati 1718	7.5	8.1	344.23	378.88
V_2 - Pusa Basmati 1847	7.8	8.5	440.24	481.91
V_3 - Pusa Basmati 1886	7.2	7.8	318.35	350.47
S Em±	0.06	0.05	4.51	5.57
CD (P=0.05)	0.23	0.21	17.69	21.87
Nitrogen levels (Sub-plot)				
N_0 - Control	6.3	5.5	266.99	235.33
N_1 - 100% N (Prilled Urea)	7.8	8.7	397.47	446.89
N_2 - 50% N (Prilled Urea) +2 foliar application of Nano Urea	7.3	8.2	344.09	393.97
N_3 - 50% N (Prilled Urea) + Green manuring +1 foliar application of Nano Urea	7.5	8.3	360.36	404.57
N_4 - 75% N (Prilled Urea) + 2 foliar application of Nano Urea	7.9	8.8	406.81	459.59
N_5 - 75% N (Prilled Urea) + 1 foliar application of Nano Urea + Green manuring	8.1	9.1	429.93	482.18
S Em±	0.07	0.07	5.43	5.14
CD (P=0.05)	0.21	0.2	15.67	14.85