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Effect of different types of fertilization on growth parameters, yield and economics of wheat (*Triticum aestivum* L.)

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Abstract
A significant cereal crop, wheat (*Triticum aestivum* L.) is a member of the genus *Triticum* and family *Poaceae*. It is the most significant cereal crop in the world, making up 30% of all cereal foods produced worldwide and serving as a staple diet for around 10 billion people across 43 countries. It is the main staple food and the biggest grain crop in India. The term "King of Cereals" is commonly used to describe wheat. In order to evaluate the "Effect of different types of fertilization on chlorophyll content, soil properties, quality, and productivity of wheat (*Triticum aestivum* L.)" during the Rabi season of 2024–2025, a field experiment was conducted at AICRP on Integrated Farming System, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was conducted in randomized block design (RBD), replicated thrice with ten different treatment combinations were used in the experiment which includes T_1 – Absolute control, T_2 - RDF (120:60:60 NPK kg ha^{-1}), T_3 - 25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30, 45 and 60 DAS, T_4 - 50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS, T_5 - 75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS, T_6 - 50%RDN+100%RDK+ one foliar spray of monoammonium phosphate(12:61:0) at 45 Das, T_7 – 100% RDP + three foliar spray of potassium nitrate (13:0:45) 30,45 and 60 DAS, T_8 -25% RDF + Three foliar sprays of Nano Urea at 30, 45, and 60 DAS, T_9 -50% RDF + Two foliar sprays of Nano Urea at 45 and 60 DAS and T_{10} - 75% RDF+ One foliar spray of Nano Urea at 45 DAS.

Keywords: Ammonium phosphate, fertilization, foliar spray, nano urea, potassium nitrate

Introduction
A significant cereal crop, wheat (*Triticum aestivum* L.) is a member of the genus Triticum and family Poaceae. Wheat can withstand a variety of soil types, has good winter hardiness, and can burn up in extreme heat. It is the main staple food and the biggest grain crop in India. The term "King of Cereals" is commonly used to describe wheat. Wheat is a nutritious crop that provides 327 calories and is a rich source of various essential nutrients, including protein, dietary fiber, manganese, phosphorus, and several B vitamins. Gluten accounts for 75-80% of the protein found in wheat. Wheat is a good source of niacin and thiamine. It contains gluten, a key protein responsible for forming the elastic structure that gives bread, chapatis, and other baked goods their soft and airy texture. Protein makes up about 13% of wheat, with gluten comprising 75-80% of this protein content (Shewry *et al*., 2002) [13].

To address issues in crop production, nano-fertilizers can serve as effective tools in agriculture by enhancing pest and nutrient management. These nanomaterials possess greater penetration ability, larger surface area, and higher use efficiency, helping to minimize environmental residue. Nano-particles smaller than 100 nm can be applied as fertilizers to improve nutrient management in an eco-friendly manner and reduce pollution. Therefore, nano-particles developed through nanotechnology can be effectively integrated into the agricultural value chain to improve the overall production system.

Nanotechnology is a rapidly growing field in modern science that involves the study and manipulation of materials at the nanoscale typically between 1 and 100 nanometres. Nano-fertilizers are a form of fertilizer in which nutrients are either enclosed in nanoporous structures,

coated with thin polymer layers, or formulated as nanosized particles or emulsions (Rai *et al*., 2012) [10]. These fertilizers help boost agricultural production by enhancing nutrient efficiency and minimizing nutrient losses. They release nutrients in a controlled fashion, leading to improved crop performance. Nano Urea was introduced to farmers globally by the Indian Farmers Fertilizer Cooperative Limited (IFFCO) [3]. It is the first nano-fertilizer approved by the Government of India and officially included in the Fertilizer Control Order. Each 500 ml bottle of Nano Urea contains 40,000 mg/L of nitrogen, providing the same nutrient benefit as a conventional bag of urea. As an indigenously developed liquid fertilizer, it is economically priced at Rs. 240 per bottle about 10% less than the cost of traditional urea making it a cost-effective option. Nano Urea also helps reduce the high transportation costs linked with conventional fertilizers and cuts down government spending on urea subsidies. Additionally, a product named COAP Nano Urea, developed by the College of Agriculture, Pune, contains 13,000 mg/L of nitrogen.

The quickest way to increase crop growth is through foliar application of nutrients, which can be made available to the plants at crucial stages and will quickly and directly reach the site of food synthesis without wasting any, lowering the crop's need for fertilizer. Foliar application reduces the lag time between application and plant uptake and results in efficient nutrient absorption and utilization, making it more cost effective than other fertilization techniques. Foliar application enables deficiencies to be corrected more quickly than soil application because nutrients are immediately absorbed in the former. The fact that foliar application provides nutrients without producing phytotoxicity is an additional benefit. Applying liquid fertilizers directly to the leaves is known as foliar application, and it improves absorption in the aerial portions of the plant (Nasiri *et al*., 2010) [7].

Materials and Methods

In order to evaluate the "Effect of different types of fertilization on chlorophyll content, soil properties, quality, and productivity of wheat (*Triticum aestivum* L.)" during the Rabi season of 2024–2025, a field experiment was conducted at AICRP on Integrated Farming System, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was conducted in randomized block design (RBD), replicated thrice with ten different treatment combinations were used in the experiment which includes T_1 – Absolute control, T_2 - RDF (120:60:60 kg NPK ha^{-1}), T_3 - 25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30, 45 and 60 DAS, T_4 - 50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS, T_5 - 75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS, T_6 -50%RDN+100%RDK+ one foliar spray of monoammonium phosphate(12:61:0) at 45 Das, T_7 - 100%RDP+three foliar spray of potassium nitrate (13:0:45) 30,45and 60 DAS, T_8 -25% RDF + Three foliar sprays of Nano Urea at 30, 45, and 60 DAS, T_9 -50% RDF + Two foliar sprays of Nano Urea at 45 and 60 DAS and T_{10} - 75% RDF+ One foliar spray of Nano Urea at 45 DAS.

Biometric observations include plant height, number of tillers per hill, chlorophyll content, leaf area was recorded at different growth stages (30,60 and 90 DAS) of wheat. Plant height (cm) was measured with the help of meter scale from the base of the plant i.e., from ground level to base of the terminal bud of main shoot. The total number of tillers per hill of observational plants were counted at 30, 60 and 90 DAS. The plant pigment total chlorophyll content (SPAD) in fresh wheat leaves is determined by electronic instrument called Pedometer which measures chlorophyll content with the help of radiation sensors. The leaf area (cm2) was measured with the help of leaf area meter.

Harvested bundles of wheat plants from each net plot were threshed and winnowed separately. After cleaning, the grain was dried plot wise and then the weight was recorded and consequently grain samples were taken from each plot to determine the moisture content with the help of moisture meter. Finally, the grain yield was calculated at 12 per cent moisture before being subjected to its statistical analysis. The net plot yield was then finally converted into kg/ha.

Economics

Net monetary returns: The net monetary returns (₹ ha-1) of each treatment were worked out by deducting the mean cost of cultivation (₹ ha-1) of each treatment from the gross monetary returns (₹ ha-1) gained from the respective treatments.

Net monetary = Gross monetary returns - cost of cultivation returns (₹ ha-1)

Cost of cultivation: The cost of cultivation (₹ ha-1) of each treatment was worked out by considering the price of inputs, charges for cultivation, labour and other charges.

Benefit cost ratio

$$\text{Benefit: Cost ratio} = \frac{\text{Gross monetary returns (Rs ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

Results and Discussion

Plant height

The basal dose has an impact on the plant height data collected at 30 DAS. Compared to the control, plant height increased as a result of the basal dose. At 30 DAS, T2 had the highest plant height (22.20 cm) (RDF 120:60:60). However, T1 (absolute control) had the lowest plant height (16.44 cm). RDF and different types of fertilization foliar spray had an impact on the plant height at 60 DAS. Treatment T5 (75% RDN + 100% RDPK + one foliar spray of Nano Urea at 45 DAS) had the highest plant height at 60 DAS (61.28 cm) compared to all other treatments, with the exception of T2, T3, and T4, which were found to be comparable to treatment T5. Treatment T1, which is the absolute control, had the lowest plant height (50.47 cm).

RDF and different types of fertilization foliar spray had an impact on the plant height at 90 DAS. Treatment T5 (75% RDN + 100% RDPK + one foliar spray of Nano Urea at 45 DAS) had the highest plant height (68.10 cm) at 90 DAS compared to all other treatments, with the exception of T4, T2, and T3, which were found to be comparable to treatment T5. Treatment T1, which is the absolute control, had the lowest plant height (55.40 cm). Rawate *et al* (2022) [12].

Number of tillers $hill^{-1}$

Number of tillers data at 30 DAS varied from 1.78 to 3.66. The data recorded on number of tillers influenced due to different basal doses over control. Highest number of tillers (3.66) at 30 DAS was recorded in RDF (T2). However, the lowest number of tillers was recorded in treatment T1 (absolute control). Different types of fertilization had an impact on the number of tillers at 60 DAS. Treatment T5 (75% RDN + 100% RDPK + one foliar spray of Nano Urea at 45 DAS) had the most tillers at 60 DAS (6.64) compared to all other treatments. However, T2, T3, and T4 were found to be comparable to treatment T5. Treatment T1, which is the absolute control, had the lowest number of tillers (4.41).

Plant Height(cm)				
	Treatment details	**30 DAS**	**60 DAS**	**90 DAS**
T_1	Control without fertilizers	16.44	50.47	55.40
T_2	100% RDF (120:60:60 NPK kg ha $^{-1}$)	22.20	60.12	67.04
T_3	25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30,45 and 60 DAS	20.89	56.59	61.63
T_4	50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS	21.00	57.93	63.85
T_5	75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS	22.10	61.28	68.10
T_6	50% RDN + 100% RDK +one foliar sprays of monoammonium phosphate (12:61:0) at 45 DAS	19.42	52.33	60.72
T_7	100% RDP +Three foliar sprays of potassium nitrate (13:0:45:) 30,45 and 60 DAS	20.44	52.88	60.24
T_8	25% RDF + Three foliar spray of Nano Urea at 30,45, 60 DAS	19.40	51.81	57.52
T_9	50%RDF+Two foliar spray of Nano Urea at 45,60 DAS	21.31	53.10	56.70
T_{10}	75% RDF+ One foliar spray of Nano Urea at 45 DAS	21.85	52.53	60.60
	SE (+)	0.89	2.40	2.33
	CD @ 5%	2.65	7.13	6.92
	CV	7.54	7.57	6.60
	GM	20.51	54.90	61.18

Number of tillers (hill-1)				
	Treatment details	**30 DAS**	**60 DAS**	**90 DAS**
T_1	Control without fertilizers	1.78	4.41	4.02
T_2	100% RDF (120:60:60 NPK kg ha $^{-1}$)	3.66	6.58	7.15
T_3	25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30,45 and 60 DAS	3.29	6.54	6.56
T_4	50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS	3.51	6.43	6.53
T_5	75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS	3.39	6.64	7.72
T_6	50% RDN + 100% RDK +One foliar sprays of monoammonium phosphate (12:61:0) at 45 DAS	2.82	5.56	6.37
T_7	100% RDP +Three foliar sprays of potassium nitrate (13:0:45:) 30,45 and 60 DAS	3.01	5.47	6.40
T_8	25% RDF + Three foliar spray of Nano Urea at 30,45, 60 DAS	3.17	5.33	6.03
T_9	50%RDF+Two foliar spray of Nano Urea at 45,60 DAS	3.50	5.57	5.77
T_{10}	75% RDF+ One foliar spray of Nano Urea at 45 DAS	3.43	5.53	5.97
	SE (+)	0.18	0.35	0.41
	CD @ 5%	0.54	1.03	1.23
	CV	10.01	10.37	11.46
	GM	3.16	5.81	6.25

Different types of fertilization foliar spraying varies the number of tillers per hill at 90 DAS. Treatment T5 (75% RDN + 100% RDPK + one foliar spray of Nano Urea at 45 DAS) had the most tillers at 90 DAS (7.72) compared to all other treatments, with the exception of T4, T2, and T3, which were found to be comparable to treatment T5. In contrast, treatment T1 (absolute control) had the fewest tillers (4.02). Similar finding was found Raut *et al*. (2024) Found that 75% RDN + 100% RDPK + one nano urea spray increased the number of tillers to 7.7 plant^{-1} compared to 6.83 in 100% RDF and 3.24 in the unfertilized control. Shinde *et al*. (2023) [14].

Leaf area

The application of various basal doses of RDF, the data pertaining to wheat leaf area was determined to be significant at 30 DAS. Treatment T_2 (100%RDF) had the largest leaf area (225.00 cm^2) at 30 DAS, while T_1 (153.63 cm^2) and T_9 (162.49 cm^2) had the smallest leaf areas. According to data on wheat leaf area at 60 DAS caused by foliar sprays of different type of fertilization and variations in the basal dose of RDF, treatment T_5 (75% RDN + 100% RDPK + 1 foliar spray of Nano Urea) had the largest leaf area (1394.97cm^2) at 45 DAS, which was comparable to treatments T_2 (1330cm^2), T_3 (1300 cm^2), and T_4 (1315.50 cm^2). The lowest leaf area (946.67 cm^2) was observed in treatment T_1 (absolute control).

Different type of fertilization treatments applied foliar alter the leaf area at 90 DAS. Treatment T5 (75% RDN + 100% RDPK+1 foliar spray of Nano Urea at 45 DAS) had the largest leaf area at 90 DAS (2780.00 cm^2) compared to all other treatments, with the exception of T_2, T_4, and T_3, which were found to be comparable to treatment T_5. Conversely, T1 (absolute control) has the lowest leaf area (1954.33cm^2). Similar findings were reported by Meena *et al*. (2017) [6], Al-Shamary *et al.*, (2022) [1].

Chlorophyll content (SPAD)

treatment T_2 (100% RDF) had the highest chlorophyll content of wheat leaves at 30 DAS (37.48 SPAD) compared to control and the other treatments. Treatment T_4 (50% RDN + 100% RDPK + 2 foliar sprays of Nano Urea at 45 and 60 DAS) had the highest chlorophyll content of wheat at 60 and 90 DAS leaves (50.80 and 22.57 SPAD) compared to all other treatments, with the exception of T_5, T_7, and T_8, which were found to be comparable to treatment T_4. The treatment T_1 (control) has the lowest SPAD values. Upadhyay *et al.*, (2023) [15], Verma *et al.*, (2023) [16], Raut *et al*., (2024) [11].

Leaf area (cm^2)				
	Treatment details	**30 DAS**	**60 DAS**	**90DAS**
T_1	Control without fertilizers	153.63	946.67	1954.33
T_2	100% RDF (120:60:60 NPK kg ha $^{-1}$)	225.00	1330.00	2640.00
T_3	25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30,45 and 60 DAS	218.00	1300.00	2610.50
T_4	50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS	219.50	1315.50	2630.20
T_5	75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS	221.00	1394.97	2780.00
T_6	50% RDN + 100% RDK +one foliar sprays of monoammonium phosphate (12:61:0) at 45 DAS	185.30	1140.00	2270.00
T_7	100% RDP +Three foliar sprays of potassium nitrate (13:0:45:) 30,45 and 60 DAS	180.00	1090.00	2180.00
T_8	25% RDF + Three foliar spray of Nano Urea at 30,45, 60 DAS	184.00	1130.50	2260.30
T_9	50%RDF+Two foliar spray of Nano Urea at 45,60 DAS	162.43	953.75	1960.00
T_{10}	75% RDF+ One foliar spray of Nano Urea at 45 DAS	181.66	1142.30	2284.50
	SE (+)	11.69	73.44	150.56
	CD @ 5%	34.74	218.21	447.35
	CV	10.49	10.83	11.06
	GM	191.46	1164.79	2340.48

Chlorophyll content				
Tr no.	**Treatment details**	**30 DAS**	**60 DAS**	**90 DAS**
T_1	Control without fertilizers	29.41	41.23	15.83
T_2	100% RDF (120:60:60 NPK kg ha $^{-1}$)	37.48	44.80	19.20
T_3	25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30,45 and 60 DAS	33.01	43.10	16.73
T_4	50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS	35.80	50.80	22.57
T_5	75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS	37.27	47.76	19.13
T_6	50% RDN + 100% RDK +one foliar sprays of monoammonium phosphate (12:61:0) at 45 DAS	36.04	43.38	19.50
T_7	100% RDP +Three foliar sprays of potassium nitrate (13:0:45:) 30,45 and 60 DAS	34.10	44.62	17.97
T_8	25% RDF + Three foliar spray of Nano Urea at 30,45, 60 DAS	34.46	43.47	19.40
T_9	50%RDF+Two foliar spray of Nano Urea at 45,60 DAS	35.10	49.34	21.90
T_{10}	75% RDF+ One foliar spray of Nano Urea at 45 DAS	35.90	47.54	22.00
	SE (+)	1.27	1.13	0.70
	CD @ 5%	3.77	3.35	2.08
	CV	6.30	4.28	6.24
	GM	34.86	45.60	19.42

Yield attributes

Grain yield

The exception of T_2, T_3, T_4 which are found to be comparable to treatment T_5, grain yield has been found to be significantly higher under treatment T_5 (75% RDN + 100% RDPK+1 foliar spray of Nano Urea at 45 DAS) (3483.30 kg ha^{-1}). The absolute control, T_1, had the lowest grain yield (2344.40 kg ha^{-1}).

Straw yield

Straw yield has found highest (4822.20 kg ha^{-1}) under T_5 (75% RDN + 100% RDPK+1 foliar spray of Nano Urea at 45 DAS) over all other treatments except T_2, T_3 and T_4 which were at par with treatments T_5. The lowest straw yield was recorded (3233.30 kg ha^{-1}) in treatment T_1 (Absolute control).

Tr no.	Treatment details	Grain yield (Kg ha-1)	Straw yield (kg ha-1)
T_1	Control without fertilizers	2344.40	3233.30
T_2	100% RDF (120:60:60 NPK kg ha $^{-1}$)	3422.20	4755.50
T_3	25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30,45 and 60 DAS	3266.60	4583.30
T_4	50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS	3316.60	4577.70
T_5	75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS	3483.30	4822.20
T_6	50% RDN + 100% RDK +one foliar sprays of monoammonium phosphate (12:61:0) at 45 DAS	2833.30	3927.70
T_7	100% RDP +Three foliar sprays of potassium nitrate (13:0:45:) 30,45 and 60 DAS	2888.80	3961.10
T_8	25% RDF + Three foliar spray of Nano Urea at 30,45, 60 DAS	2650.00	3683.30
T_9	50%RDF+Two foliar spray of Nano Urea at 45,60 DAS	2850.00	3933.30
T_{10}	75% RDF+ One foliar spray of Nano Urea at 45 DAS	3005.50	4144.40
	SE (+)	77.77	99.99
	CD @ 5%	227.77	288.89
	CV	4.42	4.06
	GM	3006.07	4162.18

Similar results were also recorded by Rawate *et al* (2022) [12], Pal *et al.,* (2023) [9], Raut *et al.,* (2024) [11].

Economics of wheat

Cost of cultivation (Rs ha^{-1})

Wheat crop applied with treatment T_2 (RDF) accounted the highest cost of cultivation (66836.00 Rs ha^{-1}) among all other treatments. It was followed by application of T_5 (66273.00 Rs ha^{-1}). This may be due to high cost of fertilizers used for soil basal application as RDF. While, the lowest cost of cultivation found with T_1 (control) only (57008.00 ₹ha^{-1}).

Gross monetary returns (₹ ha^{-1})

Mean gross monetary returns of wheat crop obtained was (89416.38 Rs ha^{-1}). Significantly, the highest gross monetary returns (104670.00 Rs ha-1) obtained in wheat with the application of treatment T_5(75% RDN + 100% RDPK + 1 foliar spray of Nano Urea at 45 DAS) as compared to other treatments followed by application of treatment T_2 (RDF) (102660.00 Rs ha^{-1}). The lowest gross monetary returns found with treatment T_1

(control) (70320.00 Rs ha^{-1}). The highest gross monetary returns documented because of higher grain yield and straw yield due to foliar application of Nano urea to wheat crop.

Net monetary returns (Rs ha^{-1})

Treatment T_5 (75% RDN + 100% RDPK + one foliar spray of Nano Urea at 45 DAS) produced significantly higher net monetary returns (38397.00 Rs ha-^{1}) followed by T_2-RDF (35824.00 Rs ha^{-1}). Significantly, the lowest net monetary returns documented with of Control treatment (13312.00 Rs ha^{-1}). The higher grain and straw yield with lower cost of cultivation were responsible for getting the highest net monetary returns in wheat crop. These results are in conformity with Nitharwal *et al.* (2022) [8].

B:C ratio

The B:C ratio is related with gross monetary returns and cost of cultivation. The wheat crop applied with application of, treatment T_5 (75% RDN + 100% RDPK + 1 foliar spray of Nano Urea at 45 DAS) documented the highest B:C ratio (1.58) because of getting the highest gross monetary returns as compared to other treatments. It was followed by followed by T_2 RDF (1.54). While, the lowest B:C ratio accounted with Control treatment (1.23). Nitharwal *et al.* (2022) [8], Raut *et al*., (2024) [11] and Dhaker *et al.* (2022) [2] found similar outcomes about B:C ratio in wheat crop.

Tr. No.	Economics				
		GMR	NMR	CC	B:C
T1	Control without fertilizers	70320.00	13312.00	57008.00	1.23
T2	100% RDF (120:60:60 NPK kg ha $^{-1}$)	102660.00	35824.00	66836.00	1.54
T3	25% RDN + 100% RDPK + Three foliar sprays of nano urea at 30,45 and 60 DAS	92490.00	27171.00	65319.00	1.42
T4	50% RDN + 100% RDPK + Two foliar sprays of Nano Urea at 45 and 60 DAS	99510.00	33713.00	65797.00	1.51
T5	75% RDN + 100% RDPK + One foliar spray of Nano Urea at 45 DAS	104670.00	38397.00	66273.00	1.58
T6	50% RDN + 100% RDK +one foliar sprays of monoammonium phosphate (12:61:0) at 45 DAS	86461.00	25700.66	60760.34	1.42
T7	100% RDP +Three foliar sprays of potassium nitrate (13:0:45:) 30,45 and 60 DAS	79392.75	20500.22	58892.53	1.34
T8	25% RDF + Three foliar spray of Nano Urea at 30,45, 60 DAS	79500.00	18727.00	60773.00	1.31
T9	50%RDF+Two foliar spray of Nano Urea at 45,60 DAS	85500.00	22723.00	62777.00	1.36
T10	75% RDF+ One foliar spray of Nano Urea at 45 DAS	90150.00	25368.00	64782.00	1.39
	SE (+)	3617.41	-	-	-
	CD @ 5%	8182.48	-	-	-
	CV	12.79	-	-	-
	GM	89416.38	26144.12	6282.15	1.41

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