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Effect of planting layout and plant spacing on growth and yield of seed production (*rabi*) of onion (*allium cepa* L.)

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Abstract
A field experiment on "Effect of planting layout and plant spacing on growth and yield of bulb production (*Kharif*) and seed production (*Rabi*) of onion (*Allium cepa* L.)" was carried out at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) with a view to study the growth and yield of onion seed production under different level of planting layout and plant spacing during *Rabi* season, 2015-16 and 2016-17. The experiment was laid out in factorial randomized block design with three replications. For the seed production in *Kharif* the treatments consisted of four planting layout viz., check basin (L_1), ridges and furrow (L_2), raised bed (L_3) and farmer practice (L_4) (Border strip) and two plant spacing viz., 60 x 20 cm (S_1) and 60 x 30 cm (S_2). Planting layout of ridges & furrow (L_2) exhibited significantly higher yield attributes and yield like number of flower stalk of onion seed production (*Rabi*) (8.33 and 9.39), height of flower stalk (81.61 and 84.90 cm), dry matter (18.12 and 19.69 g plant^{-1}), diameter of flower stalk (1.81 and 1.97 cm), diameter of umbel (7.01 and 7.50 cm), 1000 seed weight (3.78 and 3.88 g), seed yield (15.06 and 15.49 gbulb^{-1}), seed yield (423.24 and 465.01 g plot^{-1}), raw seed yield (5.60 and 6.15 q ha^{-1}), marketable seed yield (5.21 and 5.72 q ha^{-1}) and straw yield (7.69 and 8.82 q ha^{-1}) at harvesting stage which was at par with planting layout of raised bed (L_3) in respect of yield attributes like number of flower stalk (7.788 and 8.65), height of flower stalk (89.83 and 83.12 cm), dry matter (17.40 and 18.97 g plant^{-1}), diameter of flower stalk (1.62 and 1.73 cm), diameter of umbel (6.92 and 7.15 cm), 1000 seed weight (3.70 and 3.79 g). Plant spacing of 60 x 30 cm (S_2) exhibited significantly higher yield and yield attributes like number of flower stalk of onion seed production (*Rabi*) (8.46 and 9.43), dry matter (18.06 and 19.63 g plant^{-1}), diameter of flower stalk (1.72 and 1.85 cm), diameter of umbel (7.09 and 7.45 cm). But plant spacing of 60 x 20 cm (S_1) exhibited significantly higher yield and yield attributes like height of flower stalk (81.22 and 84.51 cm), seed yield (15.16 and 15.59 gbulb^{-1}), seed yield (440.09 and 483.55 g plot^{-1}), raw seed yield (5.82 and 6.40 q ha^{-1}), marketable seed yield (6.11 and 5.41 q ha^{-1}).

Keywords: Planting Layout, Plant Spacing, Check Basin, Ridges & Furrow, Raised Bed and Farmer Practice

Introduction
Onion (*Allium cepa* L.) belongs to the family Amaryllidaceae (amaryllis) or liliaceae and is one of the most important monocotyledonous, cross-pollinated and cool season vegetable crops. It originated in Afghanistan, Tajikistan and Uzbekistan, Western Tien Shan India, western Asia and the area around the Mediterranean Sea (Baloch, 1998) [3]. Onion is considerably important in the daily Indian diet. All the plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stews (MoARD, 2006) [7]. It is one of the richest sources of flavonoids in the human diet which is relevant given that the flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. Flavonoids are not only anti-cancer, but also are known to be anti-bacterial, antiviral, antiallergenic and anti-inflammatory. The unavailability of quality onion seeds is greatly responsible for low yield in this region. The onion's seed size and weight affect the final yield. Furthermore, high quality seed is the critical input on which all other inputs depend for their potential yield. Thus, the yield of this spice is influenced by many factors but cultivars, soil and climate, seedling age, bulb weight, spacing, date of planting and seed quality are very important. Observed the best yield of onion with large size mother bulb (20 g). Moreover, onion is known to be a thermo-photo sensitive plant. So, due to environmental limitations, such as short winter season, the plants raised from seeds in most

Cases do not bear good seeds in the same season in India. In this situation, many breeders (seed companies) transfer onion seed production to areas with optimal climate conditions in order to lower risk of losing crops. However, Bulb-to-seed method is appropriate for onion seed production in India. Due to lack of adequate information on different aspects of seed production, such as proper size of mother bulbs, the growers are reluctant to seed production. Bulb size and plant spacing are the key factors in producing quality onion seeds. However, the information on bulb size and plant spacing of the cultivar is very low in respect of seed production. Therefore, the present study was conducted to investigate the effects of bulb size and plant spacing on seed production of onion cultivar in India. The estimated requirement of quality seed of onion is 3120 t (assuming seed rate 6 kg ha^{-1}) during 2002 and out of that only 9.6 per cent of the demand is catered by public sectors organizations viz; NHRDF, NSC, ICAR institutes (IARI &, IIHR) and SAU's). The most of the demands of the quality seed was either meet by private sectors or unorganized program or own saved seed. Therefore, it is becomes important to increase the supply of quality seed through the efficient use of the technology. On the other hand sincere efforts should be made for the developed and release of hybrids. Agricultural production and productivity are influence by several factors of them, seed is the vital input which significantly helps in enhancing the productivity of crops. The seed production of onion is very difficult phenomena as it is produced in two phases. In first phase, the bulb production is required, while under second phase the seed production takes place from the bulbs. There is no recommendation made even in the region with regard to onion plant spacing. The present study was therefore, undertaken to investigate the effects of different intra-row spacing on the growth and yield of onion and investigate new option to increase the farmer profit by putting attention of farmer towards seed production instead of selling onion bulb at low price and avoid farmer loss. Hence spacing management is very effective in onion. At present very meager research work has been carried on plant spacing and land configuration in onion.

Material and methods

The experiment was carried out in the plot having survey No. 134/2 during the first year 2015-16 and in survey No. 134/4 for second year 2016-17 at Post Graduate Research Farm, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar district (Maharashtra) which are situated at 19^0 21' N latitude and 74^0 38' E longitude and on altitude of about 436 meters above the mean sea level (MSL). The experiment was laid out in factorial randomized block design with three replications. For the seed production in *Rabi* the treatments consisted of four planting layout viz., check basin (L_1), ridges and furrow (L_2), raised bed (L_3) and farmer practice (L_4) (Border strip) and two plant spacing viz., 60 x 20 cm (S_1) and 60 x 30 cm (S_2). Planting of onion bulb was done on 16th December and 17th December during the year 2015 and 2016, respectively. The bulb of onion is treated with carbendazim 3 gm per liter of water. Due care was taken to keep rhizosphere sufficiently moist in order to ensure proper establishment of plants up to 15 days. The treatments were imposed thereafter. To maintain the optimum plant population, gap filling was carried out as soon as the mortality was notice after planting. The gap filling was done on 28.12.2015 and 30.12.2016 during first and second year of experiment.

Results and Discussion

Effect of plant and spacing on growth parameters of onion seed production

Plant Height (cm)

The plant height of onion was influenced significantly due to the different Level of planting layout. Significantly more height at all the stages of crop growth during both the years was recorded when crop was transplanted on ridges and furrow (L_2). Plant spacing of 60 x 20 cm (S_1) registered significantly higher periodical plant height at all the crop growth stages during both years. Significantly minimum plant height was recorded under treatment 60 x 30 cm (S_2) at all the crop growth stages during both the years.

Days to Bulb Sprouting

The days required to bulb sprouting was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly minimum days required to bulb sprouting (13.42 and 14.83). Plant spacing of 60 x 20 cm (S_1) recorded significantly shows minimum days required to bulb sprouting (13.44 and 14.99) than plant spacing of 60 x 30 cm (S_2) (14.68 and 16.23) during both the years respectively.

Days to 50 Per Cent Umbel Initiation

The days required to 50 per cent umbel initiation was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly minimum days required to 50 per cent umbel initiation (49.48 and 52.42). Plant spacing of 60 x 20 cm (S_1) recorded significantly shows minimum days required to 50 per cent bolting (49.38 and 52.52) than plant spacing of 60 x 30 cm (S_2), (51.93 and 54.98) during both the years respectively. The lowest (49 days) and the highest (51 days) number of days to 50% umbel initiation were achieved at 20 and 30 cm intra-row spacing, respectively

Days to Maturity

The days required to maturity was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly minimum days required to maturity (126.00 and 130.17). Plant spacing of 60 x 20 cm (S_1) recorded significantly shows minimum days required to maturity (125.50 and 129.67) than plant spacing of 60 x 30 cm (S_2), (128.79 and 132.62) during both the years respectively. The lowest (125 days) and the highest (128 days) number of days to maturity were recorded at 20 and 30 cm intra-row spacing, respectively.

Dry Matter $Plant^{-1}$ (g)

The dry matter $plant^{-1}$ (g) was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly maximum dry matter $plant^{-1}$ (g) (18.12 and 19.69). Plant spacing of 60 x 30 cm (S_2) recorded significantly shows maximum dry matter $plant^{-1}$ (g), (18.06 and 19.63) than plant spacing of 60 x 20 cm (S_1), (16.56 and 18.00) during both the years respectively.

Effect of plant and spacing on yield parameters of onion seed production

Number of Flower Stalk $Bulb^{-1}$

Planting layout levels of ridges and furrow (L_2) recorded significantly maximum number of flower stalk (8.33 and 9.39). Plant spacing of 60 x 30 cm (S_2) recorded significantly shows maximum number of flower stalk (8.46 and 9.43) than

plant spacing of 60 x 20 cm (S_1), (6.53 and 7.40) during both the years respectively

Height of Flower Stalk (cm)

The height of flower stalk was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly maximum height of flower stalk (81.61 and 84.90). Plant spacing of 60 x 20 cm (S_1) recorded significantly shows maximum height of flower stalk (81.22 and 84.51) than plant spacing of 60 x 30 cm (S_2), (77.40 and 81.27) during both the years respectively.

Diameter of Flower Stalk (cm)

The diameter of flower stalk (cm) was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly maximum diameter of flower stalk (cm), (1.81 and 1.97). Plant spacing of 60 x 30 cm (S_2) recorded significantly shows maximum diameter of flower stalk (cm), (1.72 and 1.85) than plant spacing of 60 x 20 cm (S_1), (1.49 and 1.60) during both the years respectively.

Diameter of Umbel (cm)

The diameter of umbel (cm) was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly maximum diameter of umbel (cm), (7.01 and 7.50). Plant spacing of 60 x 30 cm (S_2) recorded significantly shows maximum diameter of umbel (cm), (7.09 and 7.45) than plant spacing of 60 x 20 cm (S_1), (6.65 and 6.88) during both the years respectively.

1000 Seed Weight (g)

The 1000 seed weight (g) was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly maximum 1000 seed weight (g), (3.78 and 3.88). Plant spacing of 60 x 30 cm (S_2) recorded significantly shows maximum 1000 seed weight (g), (3.80 and 3.89) than plant spacing of 60 x 20 cm (S_1), (3.50 and 3.59) during both the years respectively.

Marketable Seed Yield (q ha^{-1})

The marketable seed yield (q ha^{-1}) was influenced significantly due to the different planting layout levels. Planting layout levels of ridges and furrow (L_2) recorded significantly maximum marketable seed yield (q ha^{-1}), (5.21, 5.72 and 5.46). during the first, second year and pooled mean basis, respectively. Inversely, planting layout levels of farmers practice (L_4) recorded significantly shows minimum marketable seed yield (q ha^{-1}), (4.38, 4.65 and 4.52) during the first and second year and pooled mean basis, respectively. Plant spacing of 60 x 20 cm (S_1) recorded significantly shows maximum marketable seed yield (q ha^{-1}), (5.41, 5.95 and 5.68) than plant spacing of 60 x 30 cm (S_2), (4.34, 4.58 and 4.46) during both the years and pooled mean basis, respectively.

Straw Yield (q ha^{-1})

Planting layout levels of ridges and furrow (L_2) recorded significantly maximum straw yield (q ha^{-1}), (40.61, 44.34 and 42.47). during the first, second year and pooled mean basis, respectively. Plant spacing of 60 x 20 cm (S_1) recorded significantly shows maximum straw yield (q ha^{-1}), (41.59, 45.18 and 43.38) than plant spacing of 60 x 30 cm (S_2), (36.20, 39.77 and 37.98) during both the years and pooled mean basis, respectively.

Effect of plant and spacing on Economics of onion seed production

Cost of cultivation

Planting layout level of raised bed (L_3) recorded numerically maximum cost of cultivation for onion crop (204387, 214178 and 209282 ₹ ha^{-1}) as compared to planting layout level of ridges and furrow (L_2), (203470, 212995 and 208233 ₹ ha^{-1}), planting layout at check basin (L_1), (202187, 211338 and 206763 ₹ ha^{-1}) and planting layout at farmer practice (L_4), (202187, 211338 and 206763 ₹ ha^{-1}) during both the years and on pooled mean basis, respectively. The plant spacing levels of 60 x 20 cm (S_1) recorded numerically maximum cost of cultivation for onion (230029, 240207 and 235118 ₹ ha^{-1}) than plant spacing levels of 60 x 30 cm (S_2), (176087, 184718 and 180402 ₹ ha^{-1}) during both the years and on mean basis, respectively.

Gross monetary returns

Planting layout at ridges and furrow (L_2) recorded significantly maximum gross monetary returns for onion crop (528761, 924126 and 726443 ₹ ha$_{-1}$) as compared to planting layout level of raised bed (L_3) (520721, 896544 and 708633 ₹ ha$_{-1}$) and planting layout at check basin (L_1), (487532, 831716 and 659624 ₹ ha^{-1}) and planting layout farmer practice (L_4), (445835, 751617 and 598726 ₹ ha^{-1}) during both the years pooled mean basis, respectively. The plant spacing of 60 x 20 cm (S_1) recorded significantly maximum gross monetary returns for onion crop (549701, 960824 and 755262 ₹ ha^{-1}) than plant spacing levels of 60 x 30 cm (S_2), (441723, 741178 and 591450 ₹ ha^{-1}) during both the years and in pooled mean basis, respectively.

Net monetary returns

The net monetary returns ₹ ha-1 of onion crop was influenced significantly due to the different planting layout levels. of ridges and furrow (L_2) recorded significantly maximum net monetary returns (325290, 711131 and 518210 ₹ ha^{-1}) as compared to planting layout level of raised bed (S_3), (316334, 682365 and 499350 ₹ ha^{-1}) and planting layout level of check basin (285344, 620377 and 452861 ₹ ha^{-1}) and planting layout level of farmer practice (L_4) (243674, 540278 and 391962 ₹ ha^{-1}) during both the years and in pooled mean, respectively. The plant spacing of 60 x 20 cm (S_1) recorded significantly maximum net monetary returns for onion crop (319672, 720616 and 520144 ₹ ha^{-1}) than plant spacing levels of 60 x 30 cm (S_2), (265635, 556460 and 411048 ₹ ha^{-1}) during both the years and in pooled mean basis, respectively.

B: C ratio

Planting layout of ridges and furrow (L_2) recorded numerically maximum B: C ratio of onion crop (2.61, 4.34 and 3.47) as compared to planting layout applied at raised bed (L_3), (2.56, 4.19 and 3.37), planting layout level of check basin (L_1), (2.42, 3.94 and 3.18) followed by planting layout designed at farmer practice (2.21, 3.55 and 2.88) during both the years and on pooled mean basis, respectively. The plant spacing levels of 60 x 30 cm (S_2) recorded numerically maximum B: C ratio of onion crop (2.51, 4.01 and 3.26) than plant spacing levels of 60 x 20 cm (S_1), (2.39, 4.00 and 3.19) during first, second and pooled mean basis, respectively.

Conclusion

Based on two years of experimentation, it could be concluded that planting layout ridges and furrow (L2) with plant spacing of 60 x 30 cm (S2) was suitable for seed production of onion

in Rabi season. For the seed production of onion planting layout of ridges and furrow (L2) along with plant spacing of 60 x 30 cm (S2) is recommended for achieving maximum growth, marketable seed yield, germination, vigour, net monetary returns and B: C ratio from onion crop transplanted during Rabi season.

Table 1: Effect of planting layout and plant spacing on growth attributing characters on onion seed production (*Rabi*) at harvest

Treatment	Plant height (cm)		Days to bulb sprouting		Days to 50 per cent umbel initiation		Days to maturity		Dry matter (g plant^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
A) Planting layouts										
L_1: Check basin	84.50	88.29	14.22	15.91	50.83	54.16	128.02	131.50	17.11	18.68
L_2: Ridges and furrow	87.28	91.07	13.42	14.83	49.48	52.42	126.00	130.17	18.12	19.69
L_3: Raised bed	85.50	89.29	13.90	15.59	49.79	52.57	126.50	130.67	17.40	18.97
L_4: Farmer practice	82.64	87.60	14.71	16.11	52.53	55.86	128.07	132.24	16.62	17.92
S Em ±	0.69	0.67	0.16	0.26	0.37	0.42	0.54	0.58	0.25	0.27
CD at 5%	2.10	2.01	0.50	0.80	1.13	1.28	1.64	1.77	0.75	0.83
B) Plant spacing										
S_1: 60 cm x 20 cm	86.89	90.68	13.44	14.99	49.38	52.52	125.50	129.67	16.56	18.00
S_2: 60 cm x 30 cm	83.07	87.44	14.68	16.23	51.93	54.98	128.79	132.62	18.06	19.63
S Em ±	0.49	0.17	0.09	0.16	0.26	0.30	0.38	0.41	0.16	0.19
CD at 5%	1.49	0.52	0.26	0.50	0.80	0.90	1.16	1.25	0.47	0.58
C) Interaction (L x S)										
S Em ±	0.98	0.35	0.17	0.33	0.53	0.60	0.76	0.83	0.31	0.39
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	84.98	89.06	14.06	15.61	50.66	53.75	127.15	131.14	17.31	18.82

Table 2: Effect of planting layout and plant spacing on yield attributing characters on onion seed production (*Rabi*) at harvest

Treatment	Number of flower stalk bulb^{-1}		Height of flower stalk (cm)		Diameter of flower stalk (cm)		Diameter of umbel (cm)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
A) Planting layouts								
L_1: Check basin	7.17	8.04	78.83	82.12	1.55	1.66	6.88	7.11
L_2: Ridges and furrow	8.33	9.39	81.61	84.90	1.81	1.97	7.01	7.50
L_3: Raised bed	7.78	8.65	79.83	83.12	1.62	1.73	6.92	7.15
L_4: Farmer practice	6.72	7.59	76.97	81.43	1.44	1.55	6.68	6.91
S Em ±	0.18	0.26	0.69	0.63	0.06	0.09	0.05	0.15
CD at 5%	0.56	0.79	2.10	1.90	0.20	0.29	0.14	0.44
B) Plant spacing								
S_1: 60 cm x 20 cm	6.53	7.40	81.22	84.51	1.49	1.60	6.65	6.88
S_2: 60 cm x 30 cm	8.46	9.43	77.40	81.27	1.72	1.85	7.09	7.45
S Em ±	0.12	0.18	0.49	0.17	0.04	0.06	0.03	0.10
CD at 5%	0.36	0.56	1.49	0.52	0.12	0.17	0.10	0.31
C) Interaction (L x S)								
S Em ±	0.24	0.37	0.98	0.35	0.08	0.11	0.07	0.21
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
General mean	7.50	8.42	79.31	82.89	1.60	1.72	6.87	7.17

Table 3: 1000 seed weight (g), Marketable seed yield and straw yield of seed onion (*Rabi*) as influenced by different treatments.

Treatment	1000 seed weight (g)		Marketable seed yield (q ha^{-1})			Straw yield (q ha^{-1})		
	2015-16	2016-17	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean
A) Planting layouts								
L_1: Check basin	3.63	3.72	4.80	5.15	4.97	5.54	6.67	6.10
L_2: Ridges and furrow	3.78	3.88	5.21	5.72	5.46	7.69	8.82	8.26
L_3: Raised bed	3.70	3.79	5.13	5.55	5.34	7.15	8.28	7.72
L_4: Farmer practice	3.49	3.57	4.38	4.65	4.52	5.17	6.30	5.73
S Em ±	0.04	0.05	0.02	0.02	0.04	0.37	0.42	0.28
CD at 5%	0.11	0.14	0.06	0.06	0.10	1.11	1.29	0.81
B) Plant spacing								
S_1: 60 cm x 20 cm	3.50	3.59	5.41	5.95	5.68	7.45	8.58	7.45
S_2: 60 cm x 30 cm	3.80	3.89	4.34	4.58	4.46	5.33	6.46	5.33
S Em ±	0.03	0.03	0.01	0.01	0.01	0.26	0.30	0.26
CD at 5%	0.08	0.10	0.04	0.04	0.03	0.79	0.91	0.79
C) Interaction (L x S)								
S Em ±	0.05	0.06	0.03	0.03	0.03	0.52	0.60	0.79
CD at 5%	NS	NS	0.08	0.08	0.08	NS	NS	NS
General mean	3.65	3.74	4.88	5.27	5.07	6.39	7.52	6.95

Table 4: Economics of onion seed production (*Rabi*) as influenced by different treatment

Treatment	Gross monetary return (₹ ha^{-1})			Cost of cultivation at Total cost (₹ ha^{-1})			Net monetary return at total cost (₹ ha^{-1})			B:C at total cost		
	Rabi 2015-16	*Rabi* 2016-17	Pooled mean	*Rabi* 2015-16	*Rabi* 2016-17	Pooled mean	*Rabi* 2015-16	*Rabi* 2016-17	Pooled mean	*Rabi* 2015-16	*Rabi* 2016-17	Pooled mean
A) Planting layouts												
L_1: Check basin	487532	831716	659624	172575	180464	176520	285344	620377	452861	2.42	3.94	3.18
L_2: Ridges and furrow	528761	924126	726443	173681	181892	177787	325290	711131	518210	2.61	4.34	3.47
L_3: Raised bed	520721	896544	708633	174471	182912	178692	316334	682365	499350	2.56	4.19	3.37
L_4: Farmer practice	445835	751617	598726	172575	180464	176520	243647	540278	391962	2.21	3.55	2.88
S.E.±	28.87	14.43	12365	14.43	43.30	135.47	144.34	142.99	12220	0.06	0.03	0.04
CD at 5%	NS	NS	NS	NS	NS	NS	437.80	433.72	35401	0.18	0.09	0.13
B) Plant spacing												
S_1: 60 cm x 20 cm	549701	960824	755262	196577	205351	200964	319672	720616	520144	2.39	4.00	3.19
S_2: 60 cm x 30 cm	441723	741178	591450	150075	157515	153795	265635	556460	411048	2.51	4.01	3.26
S.E.±	20.41	10.21	8743	10.21	30.62	95.79	102.06	101.11	8641	0.04	0.02	0.03
CD at 5%	NS	NS	NS	NS	NS	NS	309.57	306.69	25032	NS	NS	0.09
C) Interaction (L x S)												
S.E.±	40.82	20.41	34973	20.41	61.24	383.15	204.12	202.22	34564	0.08	0.04	0.12
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	495712	851001	1346713	173326	181433	354759	292654	638538	931192	2.45	4.01	6.45

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