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Nutrient Uptake of Rice Varieties as Influenced by Combination of Plant Density and Fertilizer Levels under Late Sown Conditions

O. Sampath*, A. Srinivas, T. Ramprakash and K. Avil Kumar

Department of Agronomy, College of Agriculture, Prof. Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-030, India
**Corresponding author*

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A field experiment was conducted on a sandy clay loam soil at college farm of Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Rajendranagar, Hyderabad, Telangana during the *kharif* seasons of 2014 and 2015 to study the nutrient uptake of rice varieties as influenced by combination of plant densities and fertilizers under late sown condition. Among the varieties, MTU 1010 performed superior to Pradyumna and Rajendra in nutrient uptake and yield. Under late sown conditions the variety MTU 1010 cultivated with plant density of 15 cm × 10 cm, fertility levels of 195-86-90, N, P_2O_5 and K_2O can attain highest yield.

Introduction

Rice [*Oryza sativa* (L.)] is one of the most important staple food crops in the world. However, more than 90 per cent of rice is consumed in Asia, where it is a staple food for a majority of the population, including the 560 million hungry people in the region (Mohanty, 2013). In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products. Among the rice growing countries, India has the largest area (42.27 m ha) and it is the second largest producer (105.24 m t) of rice next to China (144 m t). With an average productivity of 2.49 t ha^{-1}, though increasing marginally, but is still well below the world's average yield of 4.36 t ha^{-1} (FAOSTAT Database, 2014). At the current population growth rate (1.5 %), the rice requirement of India by 2025 would be around 125 m t (Kumar *et al.*, 2009). The importance of continuing to develop new rice varieties to guarantee India's food security and support the region's economic development needs no special emphasis. Varieties play a vital role in maximizing of yield by improving the input use efficiency. The adverse effect of late transplanting can also be minimized by selecting suitable cultivar as magnitude of yield reduction varies with the rice cultivars. Plant population exerts a strong influence on the rice growth and grain yield, because of its competitive effects, both on the vegetative and reproductive development. Optimum plant spacing ensures plants to grow properly both in their aerial and underground parts through utilization of solar radiation and nutrients, therefore proper manipulation of planting density may lead to increase in the economic yield of transplanted rice. Balanced fertilization right from the very beginning of crop growth is utmost essential to achieve better harvest of crop (Singh and Namdeo, 2004). As about 40 percent of yield increase is accounted against fertilizer use, the fertilizer recommendations should be matched to the basic soil fertility, season, target yield, climate etc. (Dakshina Murthy *et al.,* 2015). Excessive use fertilizer nutrient implies increase in cost and decrease of returns and risk of environmental pollution. On the other hand under use of nutrients depress the scope for increasing the present level of nutrients to the economically optimum level to exploit production potential to a larger extent (Singh *et al.*, 2001). Usually, rice yield declines when transplanting is delayed beyond the optimum time (Ologunde, 1987). The optimal date of transplanting of any field crop depends on the environmental conditions required for good growth and development. The farmer therefore seeks to manage the relationship between the crop and its environment in order to optimize growth and yield.

The present study is proposed to study nutrient uptake of rice varieties as influenced by combination of plant density and fertilizer levels to under late sown conditions.

Materials and Methods

Field experiment was conducted during the *kharif* season of 2014 and 2015 at Agricultural College Farm, Rajendranagar, Hyderabad. The experimental site was geographically situated at an altitude of 542.6 m above mean sea level, on 17^0 19^1 N latitude and 78^0 24^1E longitude. It comes under Southern Telangana zone of Telangana. The soil was sandy clay loam in texture, neutral in reaction (pH 7.2) with 0.49% of organic matter, with low available nitrogen (180.8 kg ha^{-1}), high available phosphorus (38.6 kg ha^{-1}) and potassium (312 kg ha^{-1}).

The experiments were laid out in a split plot design with three replications. Three varieties MTU 1010, Rajendra and Pradyumna as main plot treatments, three plant densities (P_1: 20 x 20 cm, $P_{2:}$ 15 x 15 cm and $P_{3:}$ 15 x 10 cm), three fertilizer levels ($F_{1:}$ 111-32-45, $F_{2:}$ 153-59-68 and $F_{3:}$ 195-86-90) as sub plot treatments.

The fertilizer levels111-32-45 kg NPK ha$^{-1,}$ 153-59-68kg NPK ha^{-1} and 195-86-90kg NPK ha^{-1} were applied as 50 per cent N, full dose of P and 50 per cent K at the time of transplanting. Nitrogen was applied as per the treatments in 3 split doses as basal 50% and at active tillering and panicle initiation stages 25% each. The remaining half of potassium was applied at panicle initiation stage.

Results and Discussion

Grain yield (kg ha^{-1})

During both the years, planting density, fertilizer levels and varieties significantly influenced the grain yield (Table 1).

It was observed that higher grain yield was recorded during second year than first year and it may be attributed to congenial weather parameters and yield attributes during *kharif* 2015.

The grain yield of MTU 1010 (5891, 6113 and 6002 kg ha^{-1}) was significantly higher than that of Pradyumna (5195, 5351 and 5273 kg ha^{-1}) which in turn recorded comparable grain yield with that of Rajendra (4885, 5022 and 4954 kg ha^{-1}) during both the years (2014, 2015) and in pooled means, respectively (Table 1). The increase in grain yield of MTU 1010 was 13.4, 14.2, and 13.8 per cent over Pradyumna and it was 20.6, 21.7, and 21.2 over Rajendra during 2014 and 2015 and pooled means, respectively. Yield increase in the varieties was mainly due to increase in number of productive tillers. Similar results in different varieties were noticed by various researchers viz., Ramana *et al.*, (2007); Malla Reddy and Padmaja (2013); Bhanurekha *et al.*, (2015).

Data pertaining to grain yield of rice revealed that significantly higher grain yield (6494, 6647 and 6570 kg ha^{-1}) was obtained in (T_9) *viz*., P_3 (15 cm × 10 cm) in combination with F_3 (195-86-90, N, P_2O_5 and K_2O) which was at par with (T_8) *viz*.,P_3 (15 cm × 10 cm) in combination with F_2 (153-59-68, N, P_2O_5 and K_2O) (6341, 6532 and 6437 kg ha^{-1}) with respect to rest of the treatments. Significantly the lowest grain yield was obtained with (T_1) *viz*., P_1 (20 cm × 20 cm) in combination with F_1 (111-32-45, N, P_2O_5 and K_2O) (4092, 4239 and 4165 kg ha^{-1}) when compared to other treatments. The higher grain yield might be due to the fact that higher levels of NPK led to adequate supply of nutrients to the plant resulting in better growth which in turn led to better physiological process and movement of photosynthates to sink.

The higher yield in closer plant geometry might be due to more panicle bearing shoots m^{-2}, number of spikelets $panicle^{-1}$, filled spikelets $panicle^{-1}$ and 1000-grain weight (Yadav, 2007, Navneet Aggarwal and Avtar Singh, 2015). Further, higher LAI at closer spacing might have helped the rice plants to utilize the light more efficiently resulting in higher yields (Rammohan *et al.*, 2000). The interaction effect of varieties and plant density in combination with fertility levels on grain yield during both the years and pooled means was found to be non-significant.

Straw yield (kg ha^{-1})

During both the years, planting density, fertilizer levels and varieties significantly influenced the straw yield (Table 1).

It was observed that higher straw yield was recorded during second year than first year and it may be attributed to congenial weather parameters and yield attributes during *kharif* 2015.

The straw yield of MTU 1010 (7356,7558 and 7457 kg ha^{-1}) was significantly higher than that of Pradyumna (6550, 6731 and 6640 kg ha^{-1})which in turn recorded comparable straw yield with that of Rajendra (6175, 6325 and 6250 kg ha^{-1}) during both the years (2014, 2015) and in pooled means, respectively (Table 1). The increase in straw yield of MTU 1010 was 12.3, 12.3, 12.3 per cent over Pradyumna and it was 19.1, 19.5, and 19.3 over Rajendra during 2014, 2015 and pooled means, respectively. Similar results in different varieties were noticed by various researchers viz., Mukesh *et al.*, (2013); Malla Reddy *et al.*, (2014); Bhanurekha *et al.*, (2015).

Data pertaining to straw yield of rice revealed that, significantly higher straw yield (8036, 8252 and 8144 kg ha^{-1}) was obtained in (T_9) *viz*., P_3 (15 cm × 10 cm) in combination with F_3 (195-86-90, N, P_2O_5 and K_2O) and found on par with (T_8) *viz*., P_3 (15 cm × 10 cm) in combination with F_2 (153-59-68, N, P_2O_5 and K_2O) (7915, 8127 and 8021 kg ha^{-1}) compared to rest of the treatments (Table 1). Significantly the lowest straw yield was obtained with (T_1) *viz*., P1 (20 cm × 20 cm) in combination with F_1 (111-32-45, N, P_2O_5 and K_2O) (5252, 5389 and 5321 kg ha^{-1}) when compared to other treatments. The increase in straw yield might be due to the fact that higher levels of NPK led to adequate supply of nutrients to the plant resulting in better growth which in turn led to better physiological process and movement of photosynthates to sink. Significant effect on straw yield of varieties might be due to their significant influence on plant height and tiller number as the straw is the product of these two parameters. Similar results were reported by Patra and Nayak (2001), where closer spacing of 10 × 10 cm recorded significantly higher straw yield than the wider spacing. This might be due to vigorous growth (plant height) with increase in N level, resulted in higher straw yield. Similar results were reported by Chopra and Chopra (2004) and Sandhya kanthi (2012).

The interaction effect of varieties and plant density in combination with fertility levels on straw yield during both the years and pooled means was found to be non-significant.

Table.1 Grain yield and straw yield of rice as influenced by rice varieties in relation to combination of planting densities and fertilizer levels during *kharif* 2014 and 2015

Treatments	Grain yield (Kg ha^{-1})			Straw yield (Kg ha^{-1})		
	2014	2015	Pooled	2014	2015	Pooled
Main treatments (Varieties)						
V_1- MTU 1010	5891	6113	6002	6756	7358	7257
V_2-Rajendra	4885	5022	4954	5495	6125	6050
V_3- Pradyumna	5195	5351	5273	5870	6531	6440
SEm±	57	63	60	74	75	75
CD (0.05)	223	247	235	291	295	293
Sub treatments(combination of planting density and fertilizer levels)						
T_1-P_1F_1	4092	4239	4165	5052	5189	5121
T_2-P_1F_2	4499	4660	4579	5468	5617	5543
T_3-P_1F_3	4685	4817	4751	5659	5812	5735
T_4-P_2F_1	4986	5141	5064	6147	6315	6231
T_5-P_2F_2	5378	5571	5474	6568	6748	6658
T_6-P_2F_3	5613	5814	5714	6849	7037	6943
T_7-P_3F_1	5826	6034	5930	7148	7344	7246
T_8-P_3F_2	6341	6532	6437	7715	7927	7821
T_9-P_3F_3	6494	6647	6570	7836	8052	7944
SEm±	78	78	78	105	109	107
CD (0.05)	222	222	221	300	311	306
Interaction						
SEm± (Vx T)	139	142	140	188	194	191
CD (0.05)	NS	NS	NS	NS	NS	NS
SEm± (TxV)	135	135	135	183	190	186
CD (0.05)	NS	NS	NS	NS	NS	NS

Table.2 Nitrogen uptake of rice varieties as influenced by combination of plant densities and fertilizer levels during *kharif* 2014, 2015 and pooled means

Treatments	Nitrogen uptake at harvest (kg ha^{-1})								
	Grain			Straw			Total		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Main treatments (Varieties)									
V1- MTU 1010	76.23	79.34	77.79	46.96	48.40	47.68	123.19	127.74	125.46
V2-Rajendra	54.54	59.89	57.21	38.59	40.10	39.35	93.13	99.99	96.56
V3- Pradyumna	61.94	64.97	63.46	41.66	42.80	42.23	103.60	107.77	105.69
SEm±	0.73	0.95	0.83	0.79	0.74	0.76	1.45	1.63	1.53
CD (0.05)	2.87	3.72	3.28	3.10	2.89	2.98	5.68	6.41	6.02
Sub treatments(combination of plant density and fertilizer levels)									
T_1-P_1F_1	46.91	50.48	48.69	31.81	33.16	32.48	78.72	83.63	81.18
T_2-P_1F_2	52.67	56.36	54.51	35.10	36.31	35.70	87.77	92.66	90.22
T_3-P_1F_3	55.89	59.28	57.58	36.43	37.68	37.06	92.31	96.97	94.64
T_4-P_2F_1	59.37	62.38	60.87	39.59	41.01	40.30	98.96	103.39	101.17
T_5-P_2F_2	64.91	69.05	66.98	42.90	44.47	43.68	107.81	113.52	110.66
T_6-P_2F_3	68.82	73.02	70.92	45.87	47.56	46.72	114.69	120.57	117.63
T_7-P_3F_1	70.66	74.87	72.76	46.81	48.14	47.48	117.47	123.01	120.24
T_8-P_3F_2	78.34	82.31	80.33	51.21	52.47	51.84	129.55	134.78	132.17
T_9-P_3F_3	80.57	84.87	82.72	51.90	53.11	52.51	132.47	137.98	135.22
SEm±	1.24	1.22	1.20	0.91	0.86	0.81	2.01	1.86	1.89
CD (0.05)	3.51	3.47	3.42	2.60	2.43	2.30	5.71	5.28	5.37
Interaction									
SEm± (Vx T)	2.15	2.20	2.13	1.69	1.58	1.53	3.58	3.44	3.44
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm± (TxV)	2.14	2.11	2.08	1.58	1.48	1.40	3.48	3.21	3.27
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.3 Phosphorus uptake of rice varieties as influenced by combination of plant densities and fertilizer levels during *kharif* 2014, 2015 and pooled means

Treatments	**Phosphorus uptake at harvest (kg ha^{-1})**								
	Grain			**Straw**			**Total**		
	2014	**2015**	**Pooled**	**2014**	**2015**	**Pooled**	**2014**	**2015**	**Pooled**
Main treatments (Varieties)									
V_1- MTU 1010	17.85	18.38	18.11	10.83	11.22	11.02	28.68	29.60	29.14
V_2-Rajendra	14.19	14.69	14.44	8.64	8.82	8.73	22.83	23.51	23.17
V_3- Pradyumna	14.67	15.02	14.85	8.90	9.21	9.05	23.57	24.23	23.90
SEm±	0.47	0.50	0.49	0.30	0.30	0.30	0.78	0.80	0.79
CD (0.05)	1.86	1.97	1.91	1.19	1.20	1.19	3.05	3.15	3.09
Sub treatments(combination of plant density and fertilizer levels)									
T_1-P_1F_1	10.65	10.90	10.78	6.17	6.32	6.25	16.82	17.22	17.02
T_2-P_1F_2	13.22	13.77	13.49	7.84	8.08	7.96	21.06	21.85	21.46
T_3-P_1F_3	13.72	14.07	13.90	8.10	8.42	8.26	21.83	22.49	22.16
T_4-P_2F_1	13.73	14.06	13.89	8.25	8.44	8.34	21.97	22.50	22.24
T_5-P_2F_2	16.41	16.79	16.60	10.11	10.20	10.15	26.52	26.98	26.75
T_6-P_2F_3	17.17	17.62	17.40	10.65	10.80	10.73	27.82	28.43	28.12
T_7-P_3F_1	16.33	16.93	16.63	9.98	10.37	10.18	26.31	27.31	26.81
T_8-P_3F_2	19.26	19.96	19.61	12.02	12.41	12.22	31.27	32.37	31.82
T_9-P_3F_3	19.65	20.18	19.91	11.98	12.69	12.33	31.62	32.87	32.25
SEm±	0.56	0.56	0.56	0.34	0.36	0.34	0.90	0.91	0.90
CD (0.05)	1.61	1.58	1.59	0.96	1.01	0.98	2.56	2.58	2.56
Interaction									
SEm± (Vx T)	1.04	1.04	1.03	0.63	0.66	0.64	1.66	1.68	1.67
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm± (TxV)	0.98	0.96	0.97	0.59	0.62	0.60	1.56	1.57	1.56
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.4 Potassium uptake of rice varieties as influenced by combination of plant densities and fertilizer levels during *kharif* 2014, 2015 and pooled means

Treatments	Potassium uptake at harvest (kg ha^{-1})								
	Grain			Straw			Total		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Main treatments (Varieties)									
V_1- MTU 1010	26.92	28.64	27.78	98.67	102.12	100.39	125.59	130.76	128.17
V_2-Rajendra	20.92	22.18	21.55	82.08	84.69	83.39	103.00	106.87	104.93
V_3- Pradyumna	23.09	24.45	23.77	87.59	90.65	89.12	110.68	115.10	112.89
SEm±	0.24	0.28	0.25	1.06	1.00	1.03	1.27	1.28	1.27
CD (0.05)	0.93	1.10	1.00	4.16	3.94	4.04	4.97	5.02	4.99
Sub treatments(combination of plant density and fertilizer levels)									
T_1-P_1F_1	16.76	18.41	17.58	68.90	71.35	70.13	85.66	89.76	87.71
T_2-P_1F_2	19.01	20.71	19.86	75.00	77.59	76.29	94.01	98.29	96.15
T_3-P_1F_3	20.23	21.40	20.81	77.53	80.18	78.85	97.75	101.58	99.67
T_4-P_2F_1	21.72	23.03	22.37	84.26	87.10	85.68	105.98	110.13	108.05
T_5-P_2F_2	24.03	25.50	24.76	90.57	93.59	92.08	114.60	119.09	116.84
T_6-P_2F_3	25.15	26.61	25.88	94.32	97.48	95.90	119.47	124.09	121.78
T_7-P_3F_1	26.12	27.66	26.89	98.62	101.88	100.25	124.75	129.54	127.14
T_8-P_3F_2	29.29	30.75	30.02	106.58	110.50	108.54	135.87	141.24	138.55
T_9-P_3F_3	30.47	31.74	31.11	109.24	112.72	110.98	139.71	144.46	142.09
SEm±	0.37	0.36	0.36	1.45	1.49	1.47	1.79	1.84	1.81
CD (0.05)	1.05	1.03	1.03	4.13	4.23	4.17	5.09	5.22	5.15
Interaction									
SEm± (Vx T)	0.65	0.66	0.65	2.60	2.63	2.61	3.18	3.26	3.22
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm± (TxV)	0.64	0.63	0.63	2.51	2.58	2.54	3.10	3.18	3.14
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Nutrient uptake studies

The pooled means of nitrogen uptake of MTU 1010 was 17.54 kg ha^{-1} at 30 DAT, 52.46 kg ha^{-1} at 60 DAT, and 125.46 kg ha^{-1} at harvest (grain + straw). The uptake of nitrogen was on par between varieties Pradyumna and Rajendra. The nitrogen uptake increased with age of crop and the highest nitrogen uptake was observed at harvest. Nitrogen uptake is the product of nutrient content and dry matter production. Nitrogen uptake by crop was significantly influenced by varieties, plant density in combination with fertility levels during both the years of study (Table 2). The interaction effect was non-significant.

Perusal of the data revealed that total mean uptake of nitrogen was higher (125.46 kg ha^{-1}) with MTU 1010. The mean per cent increase in N uptake with MTU 1010 over Pradyumna and Rajendra was 18.7 and 29.9 respectively. These results are in agreement with the findings of Prasada Rao *et al.*, (2011), Malla Reddy and Padmaja (2013) and Tauseef *et al.*, (2015).

Among the treatments the highest nitrogen uptake was obtained with (T_9) *viz.*,P_3 (15 cm × 10 cm) in combination with F_3 (195-86-90, N, P_2O_5 and K_2O) and was significantly superior to P_2 (15 cm × 15 cm) and P_1 (20 cm × 20 cm) at all stages of crop growth (Table 2) followed by (T_8) *viz.*,P_3 (15 cm × 10 cm) in combination with F_2 (153-59-68, N, P_2O_5 and K_2O) which were found on par. The lowest nitrogen uptake was recorded in (T_1) *viz.*, P1 (20 cm × 20 cm) in combination with F_1 (111-32-45, N, P_2O_5 and K_2O) at all stages of crop growth.

The highest nitrogen uptake was mainly attributed to proportionate increase in dry matter production and increase in total biological yield (grain + straw yield) which ultimately increased the total uptake of nitrogen. These results in conformity with research results, where high density planting recorded more nitrogen uptake than low density due to higher biomass production (Pal *et al.*, 2005) and Navneet Aggarwal and Avtar Singh (2015).

The phosphorus uptake of MTU 1010 was 3.56, 3.65, 3.61 kg ha^{-1} at 30 DAT, 11.08, 11.36, 11.22 kg ha^{-1} at 60 DAT, and 17.85, 18.38, 18.11 kg ha^{-1} in grain and 10.83, 11.22, 11.02 kg ha^{-1} in straw during 2014, 2015 and pooled means, respectively. The uptake of phosphorus was on par between varieties Pradyumna and Rajendra.

The phosphorus uptake increased with age of crop and the highest phosphorus uptake was observed at harvest. Phosphorus uptake is the product of nutrient content and dry matter production. Phosphorus uptake by crop was significantly influenced by varieties, plant density in combination with fertility levels during both the years of study (Table 3). The interaction effect was non-significant.

Perusal of the data revealed that total mean uptake of phosphorus (grain + straw) was higher (29.14 kg ha^{-1}) with MTU 1010. The mean per cent increase in P_2O_5 uptake with MTU 1010 over Pradyumna and Rajendra was 21.9 and 25.8, respectively. A progressive increase in the P uptake was observed with added levels of nitrogen up to the highest level (Sandhya kanthi, 2012).These results are in agreement with the findings of Sri Ranjitha (2011).

Among the treatments the highest phosphorus uptake was obtained with (T_9) *viz.*,P_3 (15 cm × 10 cm) in combination with F_3 (195-86-90, N, P_2O_5 and K_2O) and was significantly superior to P_2 (15 cm × 15 cm) and P_1 (20 cm × 20 cm) at all stages of crop growth followed by (T_8) *viz.*, P_3 (15 cm × 10 cm) in combination with F_2 (153-59-68, N, P_2O_5 and

K_2O) which were found on par (Table 3). The significant increase in P uptake might be due to higher root proliferation of the crop. These results are similar to the findings of Navneet Aggarwal and Avtar Singh (2015).

The pooled mean of potassium uptake of MTU 1010 was 24.19 kg ha^{-1} at 30 DAT, 58.30 kg ha^{-1} at 60 DAT, and 128.17 kg ha^{-1} at harvest (grain + straw) which was significantly superior over Pradyumna and Rajendra. The potassium uptake increased with age of crop and the highest potassium uptake was observed at harvest.

Potassium uptake is the product of nutrient content and dry matter production. Potassium uptake by crop was significantly influenced by varieties, plant density in combination with fertility levels during both the years of study (Table 4). The interaction effect was non-significant.

Perusal of the data revealed that total mean uptake of potassium was higher (128.17 kg ha^{-1}) with MTU 1010. The mean per cent increase in K_2O uptake with MTU 1010 over Pradyumna and Rajendra was 13.5 and 22.2 respectively. These results are in agreement with the findings of Sri Ranjitha (2011).

Among the treatments the highest potassium uptake was obtained with(T_9) *viz*., P_3 (15 cm × 10 cm) in combination with F_3 (195-86-90, N, P_2O_5 and K_2O) and was significantly superior to P_2 (15 cm × 15 cm) and P_1 (20 cm × 20 cm) at all stages of crop growth (Table 4). The lowest potassium uptake was recorded in (T_1) *viz*., P_1 (20 cm × 20 cm) in combination with F_1 (111-32-45, N, P_2O_5 and K_2O) at all stages of crop growth. These results are in agreement with the findings of Sandhya kanthi (2012), Singh and Namdeo (2004) and Navneet Aggarwal and Avtar Singh (2015).

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