INFLUENCE OF SOWING PATTERN AND SEED RATE ON PLANT GROWTH AND YIELD IN WHEAT

ABSTRACT

A field experiment was carried out to study the effect of different sowing pattern and seed rate on growth and yield of wheat (*Triticum aestivum)* during rabi season of 2015-16 at experimental farm of CSKHPKV, Palampur, Himachal Pradesh. The experiment with twelve treatment combinations comprising of four planting patterns (15 cm, 23 cm, 15 x 15 cm and 23 x 23 cm) and three seed rates (100, 120 and 140 kg/ha) was conducted in Randomized Block Design with four replications. The analysis of data showed that , 23 x 23 cm planting patterns significantly increased plant height (2.63 %), leaf area index (13.21%), number of spikes/m^2 (6.80%), spike length (6.31%), number of spikelets per spike (4.5%), number of grains per spike (5.57%), biological yield (7.34%), seed yield (9.86%), and seed recovery percentage (5.13%) over normal sowing (23cm). The number of shoots/m^2 after full emergence, days to 50% heading, or harvest index did not significantly differ with planting pattern. 140 kg/ha seed rate produced significantly higher number of shoots per m^2 (17.86%), leaf area index (11.76%), number of spikes per m^2 (1.53%), biological (3.94%) and seed yield (7.75%) over 100 kg/ha seed rate.

Keywords: *Triticum aestivum***,** spikelets, emergence, leaf area index, harvest index

Abbreviations: %: Per cent; @: At the rate; $^{\circ}$C: Degree Celsius; CD: Critical Difference; cm: Centimetre; et al.: et alii (and other); g: Gram; g/ha: Gram per hectare; g/m^2: Gram per square metre; ha: Hectare; K: Potassium; kg: Kilogramme; kg/ha: Kilogramme per hectare; m ha: Million hectare; m^{-2}: Per square metre; mm: Millimetre; m t: Million tonnes; N: Nitrogen; No.: Number; /: per; P: Phosphorus; pH: Power of hydrogen ions; q/ha: Quintal per hectare; t/ha: Tonne per hectare.

INTRODUCTION

Wheat (*Triticum aestivum*) is the most important crop for the majority of world's population. It is the important staple food of about two billion people (36% of the world population). It is the source of flour for the world's breadmaking. Much of the wheat used for livestock and poultry feed is a byproduct of the flour milling industry. Wheat straw is used for livestock feeding. Wheat is a nutrient-dense food that is high in carbohydrates as well as important proteins, minerals, and vitamins. Industrial uses of wheat grain include starch for paste, alcohol, oil, and gluten.

World production of wheat is 749 million tonnes, making it the second most important cereal. India is the second largest producer of wheat after China. Wheat originated in Southeast Asia. In India three species of *Triticum* mainly *aestivum*, *durum* and *dicoccum* are cultivated and occupy approximately 95, 4 and 1 per cent area, respectively. *Triticum aestivum* is cultivated in all the regions of the country while *durum* is cultivated in Punjab and Central India, and *dicoccum* in

Karnataka only. In India, wheat occupies an area of 31.61 m ha with a production of 109.52 m t and average yield of 34.64 q/ha (Anonymous 2021).

Low tillering due to prolonged low temperature at initial stages results in sub-optimal plant population and improper utilization of natural resources and other inputs. Light modifies the entire micro-environment within the crop canopy. Planting pattern too modifies the crop environment (Kler and Bains, 1992). The planting density, which is determined by seed rate, affects crop growth, nutrient uptake, tillering ability, number and weight of grains, and eventually grain production owing to inter-plant competition (Iqbal et al., 2020). Increasing the plant densities by higher seed rates had been visualized as one of the best ways to increase the yield. Appropriate planting arrangement with suitable plant population is vital for efficient use of available resources like solar radiation, soil moisture and better weed management. Uniform distribution of plants over cropped area and bidirectional orientation of plants to harvest maximum radiation through its greater penetration in crop canopy results in higher productivity.

The impact of sowing technique and seed rate on growth and yield characteristics in various crops has been extensively studied. Cross sowing significantly increased effective tillers, spikelet per ear, ear length, grains per ear and grain weight per ear and resulted in higher grain yield compared to broadcasting and line sowing (Jat and Singhi, 2004; Pandey and Kumar, 2005; Pandey and Dwivedi, 2007). Sobhani et al. (2014) also reported that there was significant interaction of planting pattern with growth and quality parameters of wheat. Nizamani et al. (2014) stated that variety Sarsabz produced highest grain production at 150 kg seed per ha while Kiran-95 and TD-1 at 125 kg seed per ha suggesting the varied response of cultivars to different seed rates. Similarily, Baloch et al. (2010) reported that higher seed rate of 150 kg/ha produced significantly better yield of wheat.

So, manipulation of agronomic practices such as planting pattern/geometry and seed rate are considered to be foremost steps to achieve proper distribution of plants over cultivated area, thereby better utilization of above and below ground natural resources towards increasing seed yield. Therefore, the goal of the current research study was to determine the best planting pattern and seed rate for higher seed production in wheat.

Materials and Methods

Experimental details

The experiment was conducted at Experimental Farm of Department of Seed Science and Technology, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi

Vishvavidyalaya, Palampur during *Rabi* 2015-16. The experimental farm is situated at 32 6' N latitude, 76 3' E longitudes at an elevation of 1290.80 m (a.m.s.l). It falls in the mid hill zone of the Shivalik ranges of Himachal Pradesh. The climate of the region is characterized as wet temperate with mild summers (March to June) and cool winters. Soil samples were collected from the field before sowing the crop from a depth of 0-30 cm for analysis of physico-chemical properties. The soil of experimental site was silty loam in texture, slightly acidic in nature and classified as *Typic Hapludalf* as per the Taxonomic Systemof Soil Classification. The physico-chemical properties of soil are given in Table 1.

Table: 1 Chemical analysis of surface soil (0-30 cm)

S. No.	Particulars	Value	Method employed
1	Available N (kg/ha)	356.1	Alkaline permanganate method (Subbiah and Asija, 1956)
2	Available P (kg/ha)	15.6	Olsen's method of extraction with 0.5 N $NaHCO_3$ at pH 8.5 (Olsen et al., 1954)
3	Available K (kg/ha)	184.7	Extraction with normal neutral Ammonium acetate and flame photometric determination (Merwin and Peech, 1950)
4	Organic Carbon (%)	0.59	Walkley and Black's rapid titration method (Walkley and Black's 1934)
5	CEC (meg./100 g soil)	10.3	Ammonium acetate saturation method (Black et al., 1965)

The treatment combinations comprising of four planting patterns (15 cm row to row, 23 cm row to row, 15 x 15 cm criss cross and 23 x 23 cm criss cross) and three seed rates (100, 120 and 140 kg/ha). The experiment was carried out using randomized complete block design with four replications. The net plot size was 3.45 x 3.45 m^2.Wheat variety HPW 236 was sown by hand plough as per planting pattern during first week of November. Seeds were dropped behind the plough in the furrow with the help of manual labour by hand. Recommended dose of nitrogen@ 120 kg/ha was applied in two equal splits through urea (46% N) half at sowing and the remaining half was top dressed at the time of first irrigation after 40 days of sowing at CRI stage by broadcast method. A uniform basal dose of 60 kg P_2O_5 and 40 kg K_2O per hectare were applied through SSP and MOP, respectively at the time of sowing, by band placement in the furrow. Isoproturon and 2,4-D were used for weed control after 40 days of sowing. Combination of isoproturon and 2,4-D @ 1.0 and 0.5 kg/ha respectively was used for the control of mixed population of weeds. Harvesting was done manually with sickles and crop produce was threshed with the help of a plot thresher.

Observations

Total numbers of shoots per m^2 after complete emergence were recorded with the help of a square grid of 0.5 m x 0.5 m which was placed randomly in the field and the shoots coming in the square grid were counted and average was worked out. Plant height was recorded from selected plants from each replication from the base of plant above soil surface to the tip of top most leaf at 30 days interval till harvesting and mean was obtained. Leaf area index was recorded at heading stage. Two rows from each side of the plot were selected. The date when heading started in those rows was recorded. Yield and yield attributes were recorded at harvest maturity. Numbers of spikes were counted from two demarcated observational units of one square meter area before harvesting. The average of these two observational units was worked out. Ten spikes were selected randomly from each plot and their length measured from the base of lower most spikelet to the tip of upper most spikelet and mean was calculated and expressed in cm. Spikelets of spikes used for spike length were counted and mean was worked out. After recording the number of spikelets the same ten spikes were threshed. The seeds were cleaned and counted and mean number of seeds per spike were recorded. After harvesting of wheat the produce per net plot area was sundried weighed and biological yield in quintal per hectare was recorded. The net plot produce after threshing obtained weighed and raw seed yield obtained was expressed in kg/ha. Raw seed per plot was graded using Indosaw Lab Seed Grader. Harvest index was worked out by using the following formula.

$$\text{Harvest index} = \frac{\text{Raw seed yield}}{\text{Biological yield}} \times 100$$

And, seed recovery percentage was worked out by using following formula.

$$\text{Seed recovery percentage} = \frac{\text{Graded seed yield}}{\text{Raw seed yield}} \times 100$$

Statistical analyses

Data on various growth and yield parameters were recorded and statistically analyzed as per procedure given by Panse and Sukhatme (1984). Least Square differences were used to test differences in treatment at 5 % level of significance.

Result and Discussion

Effect of sowing pattern and seed rate on growth attributes

The number of shoots was not influenced significantly by the sowing pattern. The outcomes were in contrast to those of Jat and Singhi (2004) and Pandey and Kumar (2005), who found that different sowing pattern affected the number of shoots per square metre. However, higher seed rate resulted in production of more number of shoots (145.0) per unit area. This was due to more number of seed sown per unit of area (Table 3). Similar outcomes were also observed by Rosy (2003).

There was no significant difference in plant height during initial stages *i.e.*, at 30 to 60 DAS. Plant height was significantly affected after 90 days of sowing. Significantly more plant height (125.5) was recorded in cross sowing at 23 cm as compare to all other treatments. The similar trend was observed during different stages of crop growth till harvest. It could be due to more LAI after 90 days of sowing which resulted in the vigorous growth of plants due to better sunlight, aeration and other micro environmental conditions as compared to other treatments. Sowing at 23 cm row spacing was at par with 15 x 15 cm cross sowing and produced significantly taller plants comparedto narrow row spacing of 15 cm (Table 2). Similar results were obtained by Tigabu and Asfaw (2016) who discovered that the height of plants was significantly affected by the different row spacings. There was no significant increase in plant height with increase in seed rate up to 140 kg/ha at all the stages of crop growth (Table 2). Similar results were reported by Rosy (2003) that different seed rates in wheat had little to no impact on plant height.

The perusal of data revealed that 50 percent heading was not significantly influenced by different sowing patterns and seed rates. This may be due to favourable climate for flowering at a particular point of time. According to Kalpana et al. (2014) studies, the alternation of row arrangement had no appreciable impact on days to 50% heading.

Consistent and significant increase in LAI was recorded in the order of 15 cm, 23 cm, 15 x 15 cmand 23 x 23 cm sowing patterns. Similarly, increase in seed rate from 100 to 140 kg/ha caused a significant increase in LAI (Table 3). This could be due to better environmental conditions of plants by proper distribution of plants resulting in increased interception, absorption, and utilization of photo synthetically active radiation (PAR), thereby resulting in higher photosynthesis and finally higher LAI in cross sowing. This could also be due to proper utilization of nutrients, water, air and sunlight in cross sowing and closer sowing. Pandey and Kumar (2005) found similar results, stating that criss-cross sowing produced much greater leaf area indices than broadcasting and line planting. Higher LAI with increase in seed rate may be due to more number of plants per unit area ultimately increased light interception and net assimilation rate depending on specific plant. Bavec et al. (2007)

also reported similar results when increased seed rates from 350 to 800 viable seeds m^2.

Effect of sowing pattern and seed rate on yield attributes

Cross sowing at 23 x 23 cmproduced significantly highest number of spikes (113.2) per unit area as compared to all other methods of sowing. Normal sowing at 23 cm row spacing also produced significantly more number of spikes than closer sowing at 15 cm (Table 3). An improvement in number of spikes under cross sowing could be on account of vigorous growth and higher tillering of plants due to more uniform distribution of sowing. Kumpawat (1998), Hussian et al. (2003) and Mekonnen (2020) reported similar results. The number of spikes was significantly influenced by the different seed rates. The number of spikes increased with increase in the seed rate. This may be because of more number of mother shoots emergence due to use of higher seed rates ultimately resulted in the establishment of more plants. This study is in line with the findings of Worku (2008) who reported that the number of productive spikes per 0.5 m row length increased linearly with increasing rates of seeding from 72.31 spikes per 0.5 m row length at the seeding rate of 100 kg ha-1 (the lowest rate) to 85.95 spikes per 0.5 m row length at the highest (150 kg ha-1) seeding rate. Kalita and Choudhary (1984), Sarkar and Torofder (1992), Ahmed et al. (1995), Kumpawat (1998), Rosy (2003) and Mekonnen (2020) all reported comparable findings for wheat.

Significantly more spike length (11.1) was recorded in cross sowing at (23 x 23 cm) compared to all othersowing patterns followed by (15 x 15 cm) spacing. It could be on account of vigorous growth of plants due to more uniform distribution of plants per unit area which resulted in proper utilizationof nutrients, water, air and sunlight in cross sowing. Normal sowing of 23 cm and closer sowing at 15 cm row spacing produced more or less similar spikes and remained at par with each other (Table 3). Prasad et al. (1991), Kler and Bains (1992), Parihar and Singh (1995), Sharma and Angrias (1996), Kumpawat (1998) and Pandey and Kumar (2005) and reported similar results in wheat. Seed rate did not affect the spike length significantly. Singh and Singh (1984), Sarkar and Torofder (1992), Singh et al. (1995) and Pandey et al. (1999) reported similar results in wheat.

More spikelets per spike (20.0) were recorded in cross sowing at (23 x 23 cm) compared to all other sowing patterns followed by (15 x 15 cm) spacing. This was due to more spike length. Normal sowing of 23 cm and closer sowing at 15 cm row spacing produced more or less similar number of spikelets per spikes and remained at par with each other (Table 3). Sharma and Angrias (1996), Sharma and Malik (1993), Jat and Singhi (2004) and Terfa (2020) reported similar results in wheat. Different seed rates did not affect the number of spikelets per spike significantly. Singh and Singh (1984) and Pandey et al. (1999) reported similar results in wheat.

More number of grains per spike was signigicantly higher (61.0) in cross sowing at (23 x 23 cm) compared to all other sowing patterns followed by (15 x 15 cm) spacing. This was due to more spike length and spikelets per spike. Normal sowing of 23 cm and closer sowing at 15 cm row spacing remained at par with each other (Table 3). Kler and Bains (1992), Sharma and Malik (1993), Kumpawat (1998), Jat and Singhi (2004), Pandey and Kumar (2005) and Bakh et al. (2007) reported similar results. Different seed rates did not affect the number of grains per spike significantly. Sarkar and Torofder (1992) and Pandey et al. (1999) reported similar results.

Cross sowing (23 x 23 cm) gave significantly higher (107.7) biological yield over other sowing patterns. Similarly, Cross-sowing (15 x 15 cm) gave significantly higher (104.7) biological yield than the line sowing. An improvement in biological yield under cross-sowing appears to be due to vigorous growth of the plants which resulted in higher biomass production due to better plant height and LAI. Normal sowing at 23 cm produced significantly more biological yield than closer sowing at15 cm (Table 3). The results were in line with research findings obtained by Kler (1988), Kaur et al. (2001a) and Hussian et al. (2003). The biological yield increased significantly with successive increase in the seed rate from 100 to 140 kg/ha. This could be because of higher plant population with increase in seed rate. Khan et al. (2000), Rosy (2003) and Tigabu and Asfaw (2016) reported similar results.

Higher seed yield (32.3) was recorded from cross sowing (23 x 23 cm) over sowing with (15 x 15 cm). Cross sowing gave significantly higher raw seed yield as compare to line sowing. Normal sowing at 23 cm produced significantly more raw seed yield than closer sowing at 15 cm (Table 3).The reason for this increase in seed yield was due to more number of shoots per unit area, more number of spikes, more number of spikelets per spike and more number of grains per spike. Kler (1988), Jain et al. (1989), Prasad et al. (1991), Kler and Bains (1992), Jadho and Nalamwar (1993), Sharma and Malik (1993), Singh et al. (1993), Angiras and Sharma (1996), Kaur et al. (2001)a, Kaur et al. (2001)b, Jat and Singhi (2004), Bakh et al. (2007), Pandey and Dwivedi (2007) and Terfa (2020) also reported similar results.

Table: 2 Effect of sowing pattern (cm) and seed rate (kg/ha) on plant height

Treatments	Plant height (cm)					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
Sowing pattern (cm)						
15	5.9	14.8	31.5	85.9	119.0	119.1
23	6.2	15.0	32.6	88.0	121.9	122.2
15 x 15	6.1	14.9	32.7	88.4	122.0	122.6
23 x 23	6.3	15.2	33.3	90.4	125.3	125.5
SE ±	0.09	0.15	0.23	0.78	0.98	0.99
CD at 5 %	**NS**	**NS**	0.66	2.24	2.81	2.83
Seed rate (kg/ha)						
100	6.1	14.9	32.2	87.0	121.6	121.6
120	6.1	15.0	32.6	88.6	122.2	122.2
140	6.1	15.0	32.8	88.9	122.5	123.3
SE±	0.08	0.13	0.20	0.68	0.85	0.83
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table: 3 Effect of sowing pattern (cm) and seed rate (kg/ha) on various plant growth and yield attributes

Treatments	Number of shoots/m^2 after complete emergence	50 percent heading stage	Leaf area index	Spike/ m^2	Spike length (cm)	Number of spikelets per spike	Number of grains per spike	Biological yield (q/ha)	Raw seed yield (q/ha)	Graded seed yield (q/ha)	Seed recovery (%)	Harvest index
Sowing pattern (cm)												
15	131.8	124.7	4.3	102.5	10.3	19.1	57.1	96.7	29.2	23.3	79.6	0.30
23	131.3	124.3	4.6	105.5	10.4	19.1	57.6	99.8	30.8	25.6	83.2	0.31
15 x 15	132.8	124.3	4.9	109.5	10.7	19.5	58.3	104.7	31.6	26.7	84.7	0.30
23 x 23	133.5	125.6	5.3	113.2	11.1	20.0	61.0	107.7	32.3	28.4	87.7	0.30
SEm±	0.81	0.51	0.08	0.95	0.10	0.10	0.22	0.44	0.15	0.12	0.43	0.00
CD at 5%	**NS**	**NS**	0.22	2.73	0.28	0.28	0.64	1.27	0.42	0.35	1.22	**NS**
Seed rate (kg/ha)												
100	119.1	124.7	4.5	103.3	10.6	19.3	58.2	100.0	29.8	25.0	83.8	0.30
120	132.9	124.8	4.8	107.3	10.7	19.4	58.4	102.5	30.9	25.9	83.9	0.30
140	145.0	124.6	5.1	112.5	10.7	19.6	58.6	104.1	32.3	27.1	83.8	0.31
SEm±	0.71	0.44	0.07	0.83	0.09	0.09	0.19	0.38	0.13	0.11	0.37	0.00
CD at 5%	2.02	**NS**	0.19	2.36	**NS**	**NS**	**NS**	1.10	0.37	0.31	**NS**	**NS**

The raw seed yield increased significantly with increase in the seed rate up to 140 kg/ha (Table 3). This could be because of higher plant population with increase in seed rate. Kalita and Choudhary(1984), Singh et al. (1985), Samra and Dhillon (1987), Kumpawat (1988), Pawar et al. (1988), Khare et al. (1989), Mahajan et al. (1991), Naik et al. (1991), Sarkar and Torofder (1992), Sharmaand Malik (1993), Singh et al. (1993), Behera (1995), Parihar and Singh (1995), Khan et al. (2000) Baloch et al. (2010), Hussain et al.(2010), Worku (2008) and Terfa (2020) also reported similar results. However, Bhargava and Shekhawat (1981)in wheat reported that different seed rates had no significant effect on seed yield.

Trend for graded seed yield was similar as reported for raw seed yield. Cross sowing (23 x 23 cm) method gave significantly higher (28.4) grain yield over cross sowing at (15 x 15 cm), normal sowing at 23 cm and closer sowing at 15 cm row spacing. Differences among the latter treatments were alsosignificant and yield decreased in the same order. Cross sowing (23 x 23 cm) planting pattern is showing 10.94% increase in graded seed yield over normal sowing at 23 cm, 6.37 % increase withcross sowing at (15 x15 cm) and 21.89% increase over closer spacing at 15 cm. Cross sowing at (15 x 15 cm) is showing 4.3% increase in graded seed yield over normal sowing at 23 cm and 14.59 % increase over closer spacing at 15 cm. However, closer spacing at 15 cm is showing 8.98%decrease in graded seed yield over normal sowing at 23 cm.

The seed yield increased significantly with increase in the seed rate up to 140 kg/ha. It was because of higher raw seed yield obtained under respective treatment.140 kg/ha seed rate is showing 8.4 % increase in graded seed yield over 100 kg/ha and 4.63% increase in yield over 120 kg/ha. Seed rate of 120 kg/ha is showing 3.6% increase in graded yield over 100 kg/ha.

It is evident from the given table 3 that sowing pattern effected seed recovery percentage significantly. Higher seed recovery percentage (87.7) was recorded with cross sowing (23 x 23 cm) overcross sowing at (15 x15 cm), normal sowing at 23 cm and sowing at 15 cm row spacing because of bold seeds obtained due to better input and available resources utilization. The recovery was significantly lowest at 15 cm normal sowing while difference due to 23 cm normal and cross sowing at (23 x 23 cm) was not significant. No significant difference was observed in seed recovery percentage due to increase in seed rates.

Harvest index

Perusal of data revealed that different sowing pattern and seed rates had no significant effect onharvest index of wheat (Table 3). Lal and Bhardwaj (1982) reported similar results.

Table: 4 Interaction effect of sowing pattern and seed rate on graded seed yield (q/ha)

	Seed rate (kg/ha)		
Sowing pattern (cm)	**100**	**120**	**140**
15	22.65	23.40	23.70
23	25.33	25.55	26.03
15 x 15	25.38	27.18	27.68
23 x 23	26.60	27.5	31.05
SE± CD 5%	0.21 0.61		

Interaction effect

The interaction effect of sowing pattern and seed rate on graded seed yield was significant. Comparison of seed yield due to different seed rates at each of the sowing pattern recorded that at closer sowing of wheat at 15 cm row spacing or cross sowing (15 x 15 cm) difference between seed yield at 120 and 140 kg/ha was not significant but it was significantly higher over 100 kg/ha. Whereas in normal sowing of wheat at 23 cm, seed yield was significantly higher at 140 kg/ha over the lower seed rates of 100 and 120 kg/ha, the difference between the latter being non significant. In cross sowing at 23 x 23 cm, seed yield increased consistently and significantly with increasing seed rate from 100 to 140 kg/ha. Comparison of sowing pattern at each seed rate exhibited interesting results. At lower seed rate of 100 kg/ha, difference in graded seed yield due to cross sowing at 15 x 15 cm and normal sowing at 23 cm was statistically same, but it was significantly highest with cross sowing at 23 x 23 cm and significantly lowest at 15 cm normal sowing. At 120 kg/ha yield trends were similar but difference between the cross sown plots at 15 x 15 cm and 23 x 23 cm was not significant, while it was significantly lowest at 15 cm normal row spacing. At highest seed rate of 140 kg/ha and a consistent and significant increase in graded seed yield was recorded in the order of 15 cm, 23 cm, 15 x 15 cm and 23 x 23 cm sowing pattern. Consequently, significantly highest graded seed yield was recorded with cross sowing at 23 x 23 cm using 140 kg/ha. However, differences due to normal sowing at 23 cm row spacing with 140kg/ha and cross sowing at 15 x 15 cm and 23 x 23 cm was not significant.

Conclusion

From the results it can be concluded that there is a positive and strong correlation between sowing pattern and seed rates on the growth, yield and yield components in wheat. The best combination for increasing wheat seed yield is criss cross sowing (23 x 23 cm) using 140 kg per hectare. An even distribution of plants over the cropped area was achieved by using a criss-cross sowing pattern and a higher seeding rate. Higher productivity results from bidirectional orientation of plants to absorb the most radiation possible through better penetration into the crop canopy, efficient utilisation of soil moisture, and better weed management.

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