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Influence of various mineral phosphorus sources on growth and yield of Maize (*Zea mays* L.) in rainfed conditions of Rawalakot, Azad Jammu and Kashmir

Shehzad, M.[1*], Hira, A.[1], Khalid, M.[1], Muhammad, J.[1], Majid, M. T[2], Mehdi, M.[3], Naeem, S.[4], Ayesha, A.[5], Muhammad, A. Q.[6], Hafiz, M. R. J.[7], Khuram, M.[8], Aqeel, A.[1] and Sadaf, K.[1]

[1]Department of Agronomy, Faculty of Agriculture, University of the Poonch, Rawalakot; [2]Department of Soil & Environmental Sciences, Faculty of Agriculture, University of Poonch, Rawalakot, Pakistan; [3]Department of Horticulture, Faculty of Agriculture, University of Poonch, Rawalakot; [4]Department of Agronomy, Bahauddin Zakariya University Multan, Pakistan; [5]Livestock and Dairy development department, Lahore, Pakistan; [6]Department of Soil &, Environmental Sciences, Faculty of Agriculturural Sciences, Ghazi University, Dera Ghazi Khan Pakistan; [7]Department of Environmental Sciences, COMSATS Institutes of Information Technology, Vehari, Pakistan; [8]Department of Agronomy, Faculty of Agriculture & Environmental Sciences, Muhammad Nawaz Shareef University of Agriculture Multan, Pakistan.

Shehzad, M., Hira, A., Khalid, M., Muhammad, J., Majid, M. T, Mehdi, M., Naeem, S., Ayesha, A., Muhammad, A. Q, Hafiz, M. R. J., Khuram, M., Aqeel, A. and Sadaf, K. (2020). Influence of various mineral phosphorus sources on growth and yield of Maize (*Zea mays* L.) in rainfed conditions of Rawalakot, Azad Jammu and Kashmir. International Journal of Agricultural Technology 16(6):1505-1514.

Abstract Inappropriate use of fertilizers is one of the reasons for low production in maize, therefore the proper use of fertilizer sources is required to boost crop production and improved soil fertility. The experiment was performed at agronomic station, University of Poonch, Rawalakot, Pakistan. Among all the Phosphorus fertilizer sources, NPK showed more significantly results for all measured variables i.e. days to 50% tasseling, days to 50% silking, days of maturity, plant height, fresh weight plant^{-1}, stem dry weight, cob fresh weight, number of cobs plant^{-1}, leaf area, number of grains cob^{-1}, 1000 kernel weight, biological yield, grain yield and phosphorus use efficiency. The tested variety, DK-919 performed better for all measured traits under rainfed conditions. Tukey's Honest significant difference test at 5% possibility was used to estimate the results.

Keywords: Inorganic phosphorus sources, Maize verities, PUE, Yield

Introduction

Maize *(Zea mays* L.) is the third most commonly dispersed cereal crops in the Pakistan (Ashraf *et al*., 2016). It is called as "Royal of cereal" because of

[*] **Corresponding Author:** Shehzad, M. ; **Email:** m.shahzaduaf@gmail.com

its great yield. In Pakistan, it is a main cash crop which is cultivated under various ecological conditions. It is mainly produced in the temperate and tropical zones. In Azad Jammu and Kashmir (AJK), total area of 196,927 thousand hectares was cultivated and areas in maize cultivation were witnessed 99,206 thousand hectares according to the annual report (Azad Jammu and Kashmir, at glance 2017-2018). Maize is considered as multipurpose cereal crop which provides food for human beings, fodder for livestock, feed for poultry and also used in textile and pharmaceutical industries. It is a major source of carbohydrates and a large dietetic value of 66.7 % starch, 10% protein, 4.8 % oil, 3% sugar, 8.5 % fiber and 1.7 % ash (Chen *et al*., 2016; Hokmalipour *et al*., 2010). Maize starch is recycled for generating bio-fuel (ethanol), and later fermentation it could be used in making plastics, paper, cellophane, photographic films, dying of clothes and paper boards. (Khodarahmpour *et al*., 2011). In the developing countries the use of modern varieties and hybrid maize are becoming popular for the improvement of crop production and to compete the population demand. However, farmers could not afford to purchase hybrid maize seeds and fertilizer due to a number of policy changes i.e. changes in subsidy policy, liberalization of input and output markets, (Akhtar *et al*., 2018). Maize hybrids play an important role in crop production (Faheed *et al*., 2016) and is fluctuated in production its response due to nutrient application (Akhtar *et al*., 2018) stated significantly influenced in plant height, sum of cobs per plant, amount of grain rows per cob, higher number of grains per cob, higher 1000-grain weight and ultimately for higher grains yield (Ali *et al.,* 2019). Now a day, the hybrid production has been successfully used for growers in all cultivated areas. In Azad Jammu and Kashmir (AJK), maize is only of the supreme essential crops and return per unit area is actual small (Azad Jammu and Kashmir, at glance 2018). Mostly, the soils of AJK comprise high organic matter content and minor to soil obtainable phosphorus (Almas *et al*., 2000). Maize absorbs huge amount of nutrients from the soil at diverse growth phases. Amongst the vital nutrients, phosphorus (P) plays an important role in improving grain yields (Akhtar *et al*., 2018). Phosphorous is another most important nutrients after nitrogen that rises profitability and production of maize. Maize crop absorbs phosphorous throughout its growing period. It is required in high amount at the stage of third and sixth week of growing period. Phosphorus added in the leaves tends to extent at maximum about mid of the growing season and declines as the plant ages (BAYER, 2019). The various inorganic phosphorus sources, such as Nitrophus (NP), Di ammonium Phosphate (DAP), Single Super Phosphate (SSP), and Triple Super Phosphate (TSP) moreover only or in blend has significantly increased the plant growth and yield for different soil conditions and properties (Ahmad *et al*., 2013). The world wide experience showed that more than 50 % of the increase in crop yields is due to fertilizers (Saidia *et al*., 2018). In Pakistan Phosphorus deficiency (<10 mg kg^{-1}) is wide spread in 90 percent soils of Pakistan percent. The use of P fertilizers is measured vital for crop production. The current phosphorus fertilizer rates on average basis are approximately one third of what is actually recommended for optimal crop production. The speedy decline in soil fertility is a collective phase of arable land in mountainous areas like most of the Azad Jammu and Kashmir, Pakistan. For soil nutrient replenishment the fertilizer application is a key strategy. The literature suggest that various inorganic sources of P fertilizer have an effect on plant development and grain yield, energy constituent and P use efficiency of maize (Mohsin *et al*., 2011).The use of phosphorus in the form of organic and inorganic resources are essential for supreme plant growth and high yield (Iqbal *et al*., 2015) which play key roles in productively cultivation systems. For sustainable crop production in Azad Jammu and Kashmir, the P-fertilizers are obligatory.

The objectives were to view the importance of phosphorus, its extensive spread deficiency and high demand and recognized to scrutinize the consequence of different Phosphorus fertilizer sources on the plant growth, yield, and phosphorus efficacy in maize cultivars under rainfed conditions of Rawalakot.

Materials and methods

The field investigation was conducted out to assess the influence of several mineral phosphorus fertilizers sources on the development of *(Zea mays* L.) under agro-climatic circumstances of Rawalakot, Azad Jammu and Kashmir. This study was performed in field trial at the study farm, near the University of Poonch Rawalakot AJK. The geography of (Rawalakot) is generally mountainous and hilly lies at 33.51 °N and 73.45 °E with a height of 1,638m. Maize (*Zea mays* L.) planted in the 2nd week of May, 2012.The crop was propagated with a single row dibbler by using seed rate of 25 kg ha^{-1} at 75 cm row to row and 20 cm plant to plant distance. Experiment was arranged in a Randomized Complete Block Design (RCBD) with factorial arrangement including three repetitions with a net plot size of 3 m x 1.5m. Two factors viz., maize hybrid and mineral P sources were as follows:- A) Maize Hybrid- $V_{1=}$ DK-919 and, $V_{2\,=}$ DK-6789; B) Mineral P sources:- T_1 = Control, T_2 = Triple super phosphate (TSP; 46% P_2O_5@ (100 kg ha^{-1}) , T_3 = Single super phosphate (SSP; 18% P_2O_5 @ 100 kg ha-^{1}), T_4 = Monoammonium phosphate (MAP; 52% P_2O_5@ 100 kg ha^{-1}), T_5 = Nitrophus (NP; 23%$_5$ P_2O_5@ 100 kg ha^{-1}), T_6 =

Diammonium phosphate (DAP; 46 P_2O_5% @ 100 kg ha^{-1}), T_7 = Potassium phosphate (KP; 35% P_2O_5@ 100kg ha^{-1}) and T_8 = Nitrogen- phosphorus-Potassium (NPK; 17% P_2O_5 @ 100 kg ha^{-1}).

Soil of the study area was collected before sowing of the crop and analysed for organic matter (0.99%), Available phosphorus (2.02 mg kg^{-1}), texture (silty clay loam), pH (6.95), EC (0.14 dSm^{-1}), N (0.087%) and moisture contents (35 %). All the growth appearances were recorded from 30 days after sowing and at biological maturity the crop was collected and all the yield components were measured. The following parameters relating to growth and yield of the crop were noted. Number of days to tasseling for individual plot was counted from the date of sowing to 50 % of the plants tasseled. The number of days to silking for each plot was counted from the date of sowing to 50% plants completed silking. Maturity day was determined from nominated plot from the date of sowing to harvest. Ten plants from each plot were randomly selected and measured the plant height. Ten plants from each treatment were taken and weighed on electric balance thereafter average fresh weight per plant was calculated. The plants were chopped to get 20 g stem from each treatment and oven dried at 65 ℃ for 48 hours and weighed on electric. Leaf area was measured at consistent intermissions of thirty days with a manageable leaf area meter. A sample of ten plants was randomly chosen from each plot. Leaves were detached with razor blade and leaf area was determined with leaf area meter. Three cobs were nominated randomly and then fresh weight was noted. Total number of cobs from each plot was recorded. From each plot, ten cobs were selected randomly and their number of grains was counted and averaged. Cobs of each plot were shoot down with an electric maize Sheller and grain sample was obtained. A sub sample of 1000 seeds were calculated from each sample and evaluated with the support of an electronic balance. After shelling, the total weight of grains from each plot was noted with a top table balance and grain yield in tons per hectare was calculated. Crop was gathered and dried for ten days. After drying, total biomass yield of each plot was certified with the help of a balance. The harvest index is the ratio of economic yield to total biological yield (grain pith and stalk) and is stated in percent. It was calculated by the subsequent formula.

$$\mathrm{H.I} = \frac{\text{Grain Yield}}{\text{Biological yield}} \times 100$$

Phosphorus use efficiency was calculated by the following formula:-

$$\mathrm{PUE} = \frac{\text{Grain Yield of Fertilized plots} - \text{grain yield of control plots}}{\text{Amount of applied phosphors}}$$

Statistical analysis

The agronomic data collected for numerous growth and yield parameters were analysed statistically with Tukey's honest significant difference test at 5% probability by using analysis of variance techniques suitable for randomized complete block design.

Table 1. Impact of phosphorus sources on yield and growth components of maize hybrids

P sources	**Days to 50 % tasselling**		**Days to 50% silking**		**Day of maturity**		**Plant height at maturity (cm)**		**Number of cobs plant^{-1}**	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
T_1	91.00^{a}	85.66^{ab}	92.66^{ab}	88.66^{abc}	137.0^{b}	141.6^{a}	175.6^{i}	173.6^{i}	2.00^{d}	1.66^{d}
T_2	76.33^{def}	79.00^{bcde}	77.66^{ghij}	87.66^{bcd}	125.0^{hi}	125.0^{hi}	237.0^{bcd}	231.6^{de}	4.66^{abc}	4.66^{abc}
T_3	79.66^{bcd}	80.00^{bcd}	89.66^{abc}	85.66^{cde}	134.0^{cd}	136.0^{bbc}	215.6^{fg}	217.9^{f}	3.66^{cd}	3.33^{cd}
T_4	79.66^{bcd}	80.00^{bcd}	79.33^{fghi}	80.00^{efghi}	130.0^{ef}	131.0^{de}	205.6^{gh}	231.1^{de}	4.00^{bcd}	3.33^{cd}
T_5	70.66^{efg}	73.33^{defg}	75.00^{hij}	75.33^{hij}	127.0^{gh}	128.3^{de}	224.5^{ef}	234.7^{cde}	3.33^{cd}	2.33^{cd}
T_6	78.00^{bcdef}	76.00^{def}	84.00^{cdef}	80.66^{efgh}	124.3^{i}	124.0^{i}	245.5^{abc}	242.2^{abcd}	4.66^{abc}	4.66^{abc}
T_7	85.66^{abc}	76.66^{cdef}	94.3^{a}	82.00^{defg}	136.0^{bc}	137.0^{b}	205.0^{gh}	$201.o^{h}$	3.33^{cd}	3.00^{cd}
T_8	67.33^{g}	69.66^{fg}	71.66^{j}	74.33^{ij}	122.6^{i}	123.6^{i}	252.3^{a}	248.6^{ab}	6.66^{a}	6.33^{ab}
Tukey's critical values	P=1.607 V= 0.803 P*V=2.273		P= 1.607 V= 0.595 P*V=1.683		for P=2.52 V=1.51 P*V=3.34		P= 3.15 V= 2.47 P*V=5.47		P= 0.4859 V= 0.2430 P*V= 0.6872	

V_1 =DK-919; V_2 = DK-6789; T_0= Control; T_1 = (TSP; P_2O_5@ 100 kg ha^{-1}); T_2 = (SSP; P_2O_5@ 100 kg ha^{-1}); T_3 = (MAP; P_2O_5@ 100 kg ha^{-1}); T_4 = (NP; P_2O_5@ 100 kg ha^{-1}); T_5 = (DAP; P_2O_5 @ 100 kg ha^{-1}); T_6 = (KP; P_2O_5@ 100 kg ha^{-1}); T_7 = (NPK; P_2O_5 @ 100+100+100 kg ha^{-1}).

Results

Results indicated that maize hybrids and P sources interaction was significantly differed (Table 1). The minimum days to 50% tasseling and 50% silking was recorded in P source (NPK) for variety DK-919 as compared to other treatments. While maximum days to 50% tasseling and days to 50% silking was prominent in control plot. P source was showed progressive influence on the development of maize. The early maturity was recorded by the treatment

NPK in DK-919 as equated to other treatments. Plant height at maturity and number of cobs plant^{-1} showed significant differences among phosphorus sources and non-significant between hybrids. Fresh weight plant^{-1}, stem dry weight and leaf area was significantly different among phosphorus sources (Table 2). Maximum Fresh weight plant^{-1}, stem dry weight and leaf area was noted in T_8 (NPK) by DK-919 which was followed by DK-6789. Cob fresh weight and Phosphorus use efficiency (PUE) could not reach to a level of significance between varieties but was statistically significant among phosphorus sources. The varities did not vary significantly for number of grain plant^{-1}, 1000-kernal weight, grain yield, biological yield and harvest index (Table 3). Phosphorus sources showed significantly different results among all the treatments for number of grain plant^{-1}, 1000-kernal weight, grain yield, biological yield and harvest index. Maximum was noted in T_8.

Table 2. Impact of phosphorus sources on yield and growth components of maize hybrids

P sources	**Fresh weight plant^{-1} (g)**		**Stem dry weight (g)**		**Leaf area (cm^2)**		**Cob fresh weight(g)**		**PUE(tha^{-1})**	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
T_0	867.3^{e}	642.3^{f}	2.74^{ef}	2.29^{g}	305.57$_{h}$	300.40$_{h}$	90.00$_{h}$	76.67$_{h}$	0.00^{i}	o.oo^{i}
T_1	1446.3^{bc}	1341.7^{cd}	3.32^{c}	3.75^{b}	705.10$_{cd}$	696.20$_{cde}$	477.33$_{cde}$	470.67$_{cde}$	25.16^{b}	23.90^{b}
T_2	1310.0^{cd}	882.3^{e}	3.02^{cde}	2.93^{de}	679.20$_{def}$	675.83$_{def}$	458.33$_{cde}$	434.00$_{ef}$	7.06^{fg}	8.73^{ef}
T_3	1448.3^{bc}	870.0^{e}	3.14^{cd}	2.93^{de}	671.80$_{ef}$	664.97$_{f}$	451.33$_{de}$	415.33$_{ef}$	16.63^{c}	18.26^{c}
T_4	1491.3^{bc}	1219.0^{d}	3.25^{cd}	3.16^{cd}	666.77$_{f}$	655.27$_{f}$	330.00$_{g}$	360.00$_{fg}$	6.23^{g}	7.80^{efg}
T_5	1596.7^{b}	1370.3^{cd}	3.67^{b}	3.78^{b}	561.83$_{g}$	551.43$_{g}$	536.33$_{bc}$	526.00$_{cd}$	25.80^{ab}	27.30^{a}
T_6	1360.3^{cd}	865.3^{e}	2.80^{ef}	2.50^{fg}	724.03$_{bc}$	717.83$_{bc}$	335.33$_{g}$	304.33$_{g}$	2.833^{h}	9.76^{e}
T_7	2005.7^{a}	1493.0^{bc}	4.34^{a}	4.00^{b}	868.7$_{a}$	742.80$_{b}$	666.33$_{a}$	610.33$_{ab}$	27.30 ^{a}	25.80$_{ab}$
Tukey's critical values	P= 146.98 V= 73.488 P*V=207.86		P=0.240 V= 0.327 P*V=0.340		P= 5.606 V= 2.80 P*V=7.928		P= 15.145 V= 7.5725 P*V= 21.41		P= 1.499 V= 0.74 P*V=2.12	

V_1 =DK-919; V_2 = DK-6789; T_0= Control; T_1 = (TSP; P_2O_5@ 100 kg ha^{-1}); T_2 = (SSP; P_2O_5@ 100 kg ha^{-1}); T_3 = (MAP; P_2O_5@ 100 kg ha^{-1}); T_4 = (NP; P_2O_5@ 100 kg ha^{-1}); T_5 = (DAP; P_2O_5 @ 100 kg ha^{-1}); T_6 = (KP; P_2O_5@ 100 kg ha^{-1}); T_7 = (NPK; P_2O_5 @ 100+100+100 kg ha^{-1}).

Table 3. Impact of phosphorus sources on yield and growth components of maize hybrids

P sources	Number of grain plant^{-1}		1000-kernal weight (g)		Grain yield (t ha^{-1})		Biological yield (t ha^{-1})		Harvest index (%)	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
T_1	259.2^{f}	271.3^{f}	55.2^{h}	99.6^{g}	1.70^{kl}	1.26^{l}	9.36^{gh}	8.00^{h}	20.66^{h}	16.107^{i}
T_2	475.3^{cd}	523.6^{bc}	248.3^{b}	243.3^{b}	6.16^{d}	5.70^{e}	16.03^{c}	17.66^{b}	38.33^{ab}	32.19^{cd}
T_3	428.6^{cde}	379.1^{de}	116.4^{fg}	138.8^{ef}	4.60^{f}	2.40^{ij}	13.23^{d}	9.23^{gh}	35.13^{bc}	25.99^{fg}
T_4	453.6^{cd}	448.3^{cd}	270.0^{ab}	153.3^{de}	3.73^{g}	2.76^{i}	12.43^{de}	9.56^{g}	30.25^{de}	28.93^{def}
T_5	482.6^{c}	521.7^{bc}	173.0^{d}	164.6^{de}	3.26^{h}	3.40^{gh}	10.23^{fg}	11.43^{ef}	31.91^{cd}	29.91^{de}
T_6	598.1^{bc}	618.0^{ab}	259.0^{ab}	258.0^{ab}	7.50^{b}	6.83^{c}	19.00^{ab}	18.46^{ab}	38.95^{a}	36.99^{ab}
T_7	341.50^{ef}	343.3^{ef}	207.3^{c}	261.0^{ab}	2.50i^{1}	1.96^{jk}	10.16^{fg}	8.10^{h}	27.62^{efg}	24.68^{g}
T_8	674.67^{a}	672.6^{a}	286.0^{a}	279.6^{a}	8.10^{a}	7.66^{ab}	19.86^{a}	19.46^{a}	40.77^{a}	39.37^{a}
Tukey's critical values	P=69.5 V=NS P*V=98.4		P=0.51 V=0.25 P*V=0.54		P=0.31 r V=0.15 P*V=0.44		P=1.02 V=0.51 P*V=1.44		P=2.69 V=1.34 for P*V= 3.81	

V_1 =DK-919; V_2 = DK-6789; T_0= Control; T_1 = (TSP; P_2O_5@ 100 kg ha^{-1}); T_2 = (SSP; P_2O_5@ 100 kg ha^{-1}); T_3 = (MAP; P_2O_5@ 100 kg ha^{-1}); T_4 = (NP; P_2O_5@ 100 kg ha^{-1}); T_5 = (DAP; P_2O_5 @ 100 kg ha^{-1}); T_6 = (KP; P_2O_5@ 100 kg ha^{-1}); T_7 = (NPK; P_2O_5 @ 100+100+100 kg ha^{-1}).

Discussion

Phosphorus sources had significant progressive role in the growth appearances of maize hybrid. Phosphorus is essential plant growth nutrient found in living plant cell which stimulate the photosynthetic activity. Application of P on dry matters and plant physical appearance resembling height, number of leaves and leaf areas are effected significantly. Maize plant gives different response to phosphorus for different varieties and soil medium. All fertilizers which contain P are increased significantly 1000-grain weight, number of grains per ear and plant height, grains yield within the hybrids (Mukhtar *et al*., 2011). Adiaha *et al*. (2016) showed the importance of mineral fertilizer (NPK) on the development of maize growth and yield. Increase in days to 50% tasseling and silking may be associated with the growth in leaf area duration and vegetative growth. As regards P sources, the unfertilized crop gave significantly greater number of days to tasseling and silking. P source such as (NPK @ 100 kg ha^{-1}) promotes the vegetative growth resulting minimum days taken to tasseling and silking. May be due to good consumption of nitrogen which is resulted in earliness Amanullah *et al*. (2007). Sometime due to environmental conditions high or low temperature may took early or late tasseling and silking. NPK source showed incredible development in tasseling and silking. Increase in days to maturity like days to heading may be due to increase in leaf area duration, vegetative growth and light use efficiency. Photoperiods, solar light and temperatures had also played a role in crop maturity. Higher days taken to maturity by crop might be climate of the growing season. Asghar *et al*. (2010) explained that number of days taken to early maturity due to more nitrogen accessibility in combination with P and K. Law-Ogbomo *et al*. (2009) and Sahmim *et al*. (2015) revealed that NPK fertilizer applications significantly increase plant height, stem thickness, and maize grains. Phosphorus is a basic structural part of the cell, especially in the form of nucleic acid, and phospholipids that may enhance the fresh weight of plant with phosphorus application. NPK fertilizer increases the speedy cell division which enhanced leaf area. Amanullah *et al*. (2009) showed significant increase in growth of maize due to P fertilizers application. Amount of grains cob^{-1} is also very significant parameter, which imperative role towards final yield. More number of cobs per plant resulted in more grains per cob. Maize hybrid was significantly influenced, number of cobs per plant, number of grain rows per cob, maximum number of grains per cob. Obaid *et al*. (2018) investigated that maximum number of cobs/plant, number of grain rows per cob, was significantly affected in maize hybrid HG-3740. Number of cobs per plant may be influenced by genetic as well as ecological factors. Bake *et al*. (2016) testified that number of grains per cob was more at definite levels of fertilizer application. Shamim *et al*. (2015) was observed the significance results of NPK fertilizer for sum of seed rows cob and number of seeds per cob. Amanullah *et al*. (2016) noted that NPK fertilizer application has significant effect on the seed size. Masood *et al*. (2011) stated that inorganic fertilizers application now a day in maize hybrids enhanced the 1000-grain weight. Faheed *et al*. (2016) stated that maize hybrids fluctuated in efficiency and showed positive response to nutrient through the growth period of the plant. Mohsin *et al*. (2011) and Mahmood *et al*. (2017) reported that inorganic P fertilizer sources showed significant effect on 1000-grain weight, grain yield, dry matter yield, total biomass yield and harvest index over control. Meena (2010) reported that the reclamation of valuable P through maize was 18-27% following the application of P sources. Our PUE consequences are reliable with Yaseen and Malhi, (2010) and Sistani *et al*. (2010).

It was concluded from this study that phosphorus source (NPK) is better for the growth and yield of maize hybrid (DK -919). NPK increases the soil physical properties and applied as the best dose for maximum maize yield in agro-climatic circumstance of Rawalakot Azad Jammu & Kashmir.

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