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Characterization of newly developed high yielding common bean (*Phaseolus vulgaris* L.) varieties 'NIFA Lobia Red-22' and 'NIFA Lobia Yellow-22'

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Abstract
Common bean (*Phaseolus vulgaris* L.) improvement program was initiated at the Nuclear Institute for Food and Agriculture (NIFA) in 2018. Germplasm from different research institutes and farmers' fields in Khyber Pakhtunkhwa (KP) was collected. The collected germplasm was evaluated in a non-replicated fashion in spring 2018 and 2019 at the research farm of NIFA, Peshawar for plant type, yield, and yield components. Six genotypes were finally selected based on seed color and growth habit, and subsequently tested in replicated yield trials conducted at NIFA, Peshawar and on farmers' fields at Charsadda in spring 2020 and 2021, at the Agricultural Research Institute (ARI), Mingora, Swat, Agricultural Research Station (ARS), Chitral in kharif 2020, and on farmers' fields at different locations in Kuram in kharif 2020 and 2021. Two genotypes, NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) out-yielded all other genotypes across all locations as well as seasons. In spring 2020 and 2021, NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) produced higher average seed yield of 2195 and 2206 kg ha^{-1}, respectively, whereas in kharif 2020 and 2021, the two genotypes produced higher average seed yield of 2082 and 2075 kg ha^{-1}, respectively, compared with those of the other genotypes. The two genotypes were approved by the KP Seed Council under the name NIFA Lobia Red-22 and NIFA Lobia Yellow-22 for general cultivation in common bean growing areas of the KP in January, 2022.

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Introduction

Common bean (*Phaseolus vulgaris* L.) is an important pulse crop having a unique position in daily diets of the Indian Sub-continent including Pakistan where it is cooked in a variety of ways. Common bean plays an important role in human health as it contains a variety of nutritional elements ranging from protein to anti-oxidants (Broughton et al., 2003; Paredes et al., 2009; Campos-Vega et al., 2011; Brigide et al., 2014; Hayat et al., 2014; Rebello et al., 2014; Kan et al., 2017; García-Díaz et al., 2018; Carbas et al., 2020). Globally, common bean was harvested from an area of 33.1 million hectares with a total production of 28.9 million tonnes (FAOSTAT, 2020). Asia contributes about 50% to global common bean production, and America, India, Myanmar, Brazil, and China are the leading producers. Despite of being an important crop, no official figures are available in any national or provincial documents regarding area and production of common bean in a country. According to individual officials of the agriculture department and growers, it is grown as an inter-crop in maize primarily for fodder in Upper Dir, Upper Swat, Upper Chitral, Upper Shangla and Upper Hazara division of KP. Kurram is the only area in

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KP where it is grown as a sole crop on vast acreage. There are a total of six approved varieties of common bean available in the country. The first variety Himalaya-1 (semi-erect type) was released by the Agricultural Research Station (ARS), Baffa, Mansehra, Khyber Pakhtunkhwa (KP), Pakistan in 2021. This variety was targeted for Hazara Division of the KP. Three more varieties of common bean namely Swat Red (semi-erect type), Green Hills (climbing type) and Gorilla (climbing type) were released by the Agricultural Research Institute (ARI), Mingora, Swat, KP in 2022. These varieties are adapted to Swat and Shangla areas of the KP. NIFA released two semi-erect type common bean commercial varieties NIFA Lobia Red-22 and NIFA Lobia Yellow-22 in 2022. These varieties were targeted for Kurram area of the KP. All these varieties are at initial stages of multiplication and in order to increase common bean production in Pakistan, continuous development of high yielding common bean varieties is direly needed.

Thus, in this manuscript characterization of the two recently developed common bean varieties has been carried out under natural field conditions in terms of their grain yield and yield components.

Materials and Methods

Different genotypes as germplasm were collected from different agricultural research institutes and farmers' fields in KP. The seeds of the collected genotypes were graded in the laboratory based on their respective uniform seed color and size. The genotypes were then field-evaluated in a non-replicated fashion for growth habit, and yield and yield attributes at the Nuclear Institute for Food & Agriculture (NIFA), Peshawar, in spring 2018. The same genotypes were again field-evaluated in a non-replicated fashion for the desired traits at NIFA in spring 2019. Based on two-year field evaluation, six genotypes were finally selected for further evaluation in replicated trials at NIFA and across-locations for testing the adaptability of these genotypes for yield and related traits under varying environmental conditions. The trials were laid-out in a Randomized Complete Block Design (RCBD). Each genotype was sown on 4 ridges of 4 m in length with ridge-to-ridge and plant-to-plant distances of 40 cm and 15 cm, respectively. Each genotype was replicated thrice. The genotypes were sown under irrigated conditions, and need-based irrigation was applied during the crop growth cycle. Statistical analyses were carried-out according to Steel and Torri (1980). Breeding history of NIFA Lobia Red-22 and NIFA Lobia Yellow-22 is given in **Table 1**. Protein analysis of the 6 genotypes was carried-out by the Food & Nutrition Division of NIFA (**Table 10**).

Table 1. Breeding history of NIFA Lobia Red-22 (NCB-Tajaki) and NIFA Lobia Yellow-22 (NCB-Watani)

Year	Activity	Remarks
2018	Collection of germplasm	NIFA Lobia Red-22 and NIFA Lobia Yellow-22 were among the germplasm collected from research institutes and farmers' fields in different areas across KP. NIFA Lobia Red-22 and NIFA Lobia Yellow-22 were collected from the farmers of Charsadda. The 22 collected genotypes were graded based on their respective seeds of uniform size and color. The genotypes were evaluated in a non-replicated fashion in a field at NIFA, Peshawar, for plant type, seed color, and yield and yield-related traits.
Spring 2019	Germplasm evaluation	Uniformly colored and sized seeds of each of 22 genotypes were again field-evaluated at NIFA for plant type, seed color, and seed yield and yield components. Based on performance in field evaluation, 6 genotypes were selected, while others were rejected due to undesirable seed color, growth habit and low yield potential. Protein analyses of the selected genotypes were also carried-out at the Food & Nutrition Laboratory of NIFA.
Spring 2020	Yield trials and DUS studies	The selected 6 genotypes were evaluated in replicated yield trials at NIFA, Peshawar, and on farmer's field at Charsadda. No disease was observed on any of the genotypes. The better performing genotypes, i.e., NCB-Tajaki with semi-erect plant type, spotted red seed color, bold seed size and high grain yield, and NCB-Watani with semi-erect plant type, yellowish seed color, medium seed size and high grain yield were evaluated for 1st year mandatory Distinctness, Uniformity and Stability (DUS) by the Federal Seed Certification & Registration Department (FSC & RD), Peshawar at NIFA on 16-06-2020.
Kharif 2020	Adaptability yield trials	The selected 6 genotypes were evaluated in adaptability yield trials at ARS, Chitral, ARI, Mingora, Swat and on farmers' fields at different locations in Kurram.
Spring 2021	Yield trials and DUS studies	The selected 6 genotypes were again evaluated in replicated yield trials at NIFA, Peshawar, and on farmer's field at Charsadda. No disease was observed on any of the genotypes. NCB-Tajaki and NCB- Watani were evaluated for 2nd year mandatory DUS by the FSC & RD, Peshawar at NIFA on 09-06-2021.
Kharif 2021	Adaptability yield trials	The said selected genotypes were evaluated in replicated yield trials on farmers' fields at three locations in Kurram.

Results and Discussion

The yield performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) is depicted in **Tables 2 to 9**. In a replicated yield trial conducted at NIFA, Peshawar, in spring 2020, NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) produced statistically significant ($P \leq 0.05$) higher seed yield of 2130 and 2343 kg ha^{-1}, respectively, compared with those of the other genotypes ranging from 1495 to 1921 kg ha^{-1} (**Table 2**). NCB-Tajaki and NCB-Watani also produced significantly higher seed yield of 2194 and 2060 kg ha^{-1} against those of the other genotypes which ranged from 1468 to 1852 kg ha^{-1} in a replicated yield trial planted on a farmer's field in Charsadda in spring 2020 (**Table 3**). In kharif 2020, in a replicated yield trial planted at ARI, Mingora, Swat, NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) produced significantly ($P \leq 0.05$) higher seed yield of 2083 and 2204 kg ha^{-1}, respectively, compared with those of the other genotypes ranging from 1556 to 1856 kg ha^{-1} (**Table 4**). In a replicated yield trial in kharif 2020 at ARS, Chitral, NCB-Tajaki and NCB-Watani produced significantly ($P \leq 0.05$) higher seed yield of 1961 and 1973 kg ha^{-1}, respectively, compared with those of the other genotypes which ranged from 1472 to 1766 kg ha^{-1} (**Table 5**). In the same season, NCB-Tajaki and NCB-Watani also produced higher average seed yield of 2055 and 2023 kg ha^{-1}, respectively, than those of the other genotypes (1524 to 1823 kg ha^{-1}) at various locations in Kurram (**Table 6**). In spring 2021, in a replicated yield trial planted at NIFA, Peshawar, NCB-Tajaki produced significantly ($P \leq 0.05$) higher seed yield of 2396 kg ha^{-1} followed by NCB-Watani (2297 kg ha^{-1}) than that of the check variety Himalaya-1 (1944 kg ha^{-1}) with 23% and 18% increase, respectively, over that of Himalaya-1 (**Table 7**). In the same season, NCB-Tajaki and NCB-Watani produced significantly ($P \leq 0.05$) higher seed yield of 2061 and 2125 kg ha^{-1}, respectively, in a replicated yield trial on a farmer's field at Charsadda than that of Himalaya-1 (1644 kg ha^{-1}) with 25% and 29% increase, respectively, in yield over that produced by Himalaya-1 (**Table 8**). NCB Tajaki and NCB-Watani also produced higher average seed yield of 2149 kg ha^{-1} and 2117 kg ha^{-1}, respectively, compared with that of Himalaya-1 (1849 kg ha^{-1}) on farmers' fields in kharif 2021 at various locations in Kurram with 16% and 14% increase in yield, respectively, over that of Himalaya-1 (**Table 9**). Improved varieties of various crops having high yield potential play a vital role in increasing crop yield and overall productivity (Ahmad et al., 2007; Wasim, 2007; deGraft-Johnson et al., 2014; Zulfiqar and Hussain, 2014; Shideed and El Mourid, 2015; Joshi et al., 2017). For growers, improved yield potential is the most favored trait in any crop (Hossain, 2012; Walker et al., 2015). High yielding crop varieties also play a positive role in enhancing farmers' income through increased yield and contribution to national food security via enhanced overall productivity and easy availability (Khoury et al., 2014; Rahman and Conner, 2022). Enhanced yield potential of NIFA Lobia Red-22 and NIFA Lobia Yellow-22 compared with other genotypes and the check variety (**Tables 2 to 9**) may play an important role in enhancing overall production of common bean in KP in particular, and the country in general.

Table 2. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) in a replicated yield trial conducted at NIFA, Peshawar in spring 2020

Genotype	DF (50%)	DM (90%)	PH (cm)	HSW (g)	SY (kg ha^{-1})
NCB-Tajaki	37	66	40	46	2130
NCB-Kenya	37	70	45	44	1921
NCB-Watani	42	75	48	35	2343
NCB-Kuram local	45	81	123	20	1704
NCB-Afghani	46	92	134	49	1495
NCB-China bean	49	88	138	28	1699
CV (%)	1.99	1.34	1.83	2.52	5.63
LSD (5%)	1.55	1.93	2.93	1.68	157.66

DF, Days to flowering; DM, Days to maturity; PH, Plant height; HSW, 100-Seed weight; SY, Seed yield

Table 3. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB-Watani (NIFA Lobia Yellow-22) in a replicated yield trial planted on farmer's field at Charsadda in spring 2020

Genotype	DF (50%)	DM (90%)	PH (cm)	HSW (g)	SY (kg ha^{-1})
NCB-Tajaki	40	68	40	47	2194
NCB-Kenya	39	68	42	43	1852
NCB-Watani	45	71	47	35	2060
NCB-Kuram local	42	85	128	20	1774
NCB-Afghani	47	85	135	50	1468
NCB-China bean	51	102	142	26	1659
CV (%)	2.28	2.03	2.99	1.59	4.93
LSD (5%)	1.78	3.04	4.84	1.06	140.86

DF, Days to flowering; DM, Days to maturity; PH, Plant height; HSW, 100-Seed weight; SY, Seed yield

Table 4. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB Watani (NIFA Lobia Yellow-22) in an adaptability yield trial conducted at ARI, Mingora, Swat in kharif 2020

Genotype	DF (50%)	DM (90%)	PH (cm)	HSW (g)	SY (kg ha^{-1})
NCB-Tajaki	40	74	43	47	2083
NCB-Kenya	42	77	47	45	1856
NCB-Watani	44	83	47	37	2204
NCB-Kuram local	49	88	125	22	1677
NCB-Afghani	50	87	126	49	1556
NCB-China bean	50	87	141	28	1731
CV (%)	1.96	1.67	3.44	1.77	5.12
LSD (5%)	1.63	2.52	5.51	1.22	177.10

DF, Days to flowering; DM, Days to maturity; PH, Plant height; SW, Seed weight; SY, Seed yield

Table 5. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB Watani (NIFA Lobia Yellow-22) in an adaptability yield trial conducted at ARS, Chitral in kharif 2020

Genotype	DF (50%)	DM (90%)	PH (cm)	HSW (g)	SY (kg ha^{-1})
NCB-Tajaki	42	78	42	45	1961
NCB-Kenya	44	80	44	43	1766
NCB-Watani	48	83	48	34	1973
NCB-Kuram local	51	89	128	19	1645
NCB-Afghani	51	97	130	47	1472
NCB-China bean	52	94	139	25	1637
CV (%)	2.70	1.33	1.49	2.86	5.24
LSD (5%)	2.36	2.09	2.37	1.85	143.80

DF, Days to flowering; DM, Days to maturity; PH, Plant height; HSW, 100-Seed weight; SY, Seed yield

Table 6. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB Watani (NIFA Lobia Yellow-22) in an adaptability yield trial planted on farmers' fields at different locations in Kurram in kharif 2020

Genotype	Seed Yield (kg ha^{-1})			
	Malana	Boshara	Shoblan	Average
NCB-Tajaki	2137	2058	1970	2055
NCB-Kenya	1863	1810	1795	1823
NCB-Watani	2040	1989	2040	2023
NCB-Kuram local	1736	1699	1778	1738
NCB-Afghani	1484	1465	1623	1524
NCB-China bean	1639	1708	1731	1693
CV (%)	5.81	5.57	4.20	-
LSD (5%)	153.96	167.16	149.0	-

Table 7. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB Watani (NIFA Lobia Yellow-22) in a replicated yield trial conducted at NIFA, Peshawar in spring 2021

Genotype	DF (50%)	DM (90%)	PH (cm)	HSW (g)	SY (kg ha^{-1})	% increase in yield over check
NCB-Tajaki	39	69	42	48	2396	23
NCB-Kenya	44	72	44	43	2088	-
NCB-Watani	46	85	44	37	2297	18
NCB-Kuram local	57	85	117	22	1736	-
NCB-Afghani	46	86	143	47	1583	-
NCB-China bean	53	86	138	23	1639	-
Himalaya-1 (Check)	46	92	38	43	1944	-
CV (%)	1.17	1.69	2.87	1.24	6.02	-
LSD (5%)	0.9	2.47	4.13	2.17	171.76	-

DF, Days to flowering; DM, Days to maturity; PH, Plant height; HSW, 100-Seed weight; SY, Seed yield

Table 8. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB Watani (NIFA Lobia Yellow-22) in an adaptability yield trial planted on farmer's field at Charsadda in spring 2021

Genotype	DF (50%)	DM (90%)	PH (cm)	HSW (g)	SY (kg ha^{-1})	% increase in yield over check
NCB-Tajaki	40	66	44	49	2061	25
NCB-Kenya	43	71	35	43	1807	-
NCB-Watani	46	72	43	35	2125	29
NCB-Kuram local	52	74	112	21	1713	-
NCB-Afghani	52	83	142	47	1102	-
NCB-China bean	54	77	134	21	1574	-
Himalaya-1 (Check)	49	91	38	44	1644	-
CV (%)	1.48	1.31	4.72	1.78	5.85	-
LSD (0.05)	1.26	1.77	6.58	1.17	164.12	-

DF, Days to flowering; DM, Days to maturity; PH, Plant height; SW, Seed weight; SY, Seed yield

Table 9. Performance of NCB-Tajaki (NIFA Lobia Red-22) and NCB Watani (NIFA Lobia Yellow-22) in an adaptability yield trial planted on farmers' fields at different locations in Kuram in kharif 2021

Genotype	Seed Yield (kg ha^{-1})				Av % increase in yield over check
	Malana	Boshara	Shoblan	Average	
NCB-Tajaki	2201	2079	2167	2149	16
NCB-Kenya	1918	1868	1889	1892	-
NCB-Watani	2188	2091	2073	2117	14
NCB-Kuram local	1859	1836	1794	1830	-
NCB-Afghani	1601	1771	1640	1670	-
NCB-China bean	1806	1888	1819	1838	-
Himalaya-1 (Check)	1866	1787	1893	1849	
CV (%)	6.67	5.95	5.68	-	-
LSD (5%)	171.21	164.09	155.34	-	-

Common bean is an important source of protein and other dietary nutrients playing an important role in human health (Compos-Vega et al., 2009; Mojica and deMejia, 2015; Chen et al., 2017; Ganesan and Xu, 2017; Gödecke et al., 2018; Chen et al., 2019). For a success of any new commercial variety of common bean, protein content coupled with high grain yield is of utmost importance, because high protein content and high grain yield define adoption as well as nutritional acceptability of a variety. NIFA Lobia Red-22 and NIFA Lobia Yellow-22 have high protein content (**Table 10**) as well as high grain yield (**Table 2 to 9**). These two varieties may therefore play a vital role in increasing overall common bean production in KP and the country as well, and may positively contribute to meet nutritional requirements.

Table 10. Protein contents of the selected six common bean genotypes and Himalaya-1 (check variety)

Genotype	Protein (%)
NCB-Tajaki (NIFA Lobia Red-22)	24.51
NCB-Watani (NIFA Lobia Yellow-22)	24.43
NCB-Kenya	24.43
NCB-Afghani	24.24
NCB-China bean	23.93
NCB-Kuram local	24.30
Himalaya-1	20.68

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Ethical approval
This study does not involve Human/animal subjects and no ethical approval is needed.

Handling of bio-hazardous materials
The author(s) certify that all experimental materials were handled with care during collection and experimental procedures. After completion of experiment, all materials were properly discorded to minimize any types of bio-contamination(s).

Availability of primary data and martials
As per editorial policy, experimental materials, primary data or software codes are not submitted to the publisher. These are available with corresponding author and/or with other author(s) as declared by the corresponding author of this manuscript.

Author's consent
All authors contributed in designing and execution of the experiment. All contributors have critically read this manuscript and agree for publishing in IJAEB.

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