Prof. T.Pullaiah,

Professor of Botany,

Sri Krishnadevaraya University,

Anantapur 515003, A.P.

The Journal of the Indian Botanical Society

Vol. XXX] JANUARY—DECEMBER 1951 [Nos. 1–4

WHEAT BREEDING INVESTIGATIONS AT THE INDIAN AGRICULTURAL RESEARCH INSTITUTE*

BY B. P. PAL

Indian Agricultural Research Institute, New Delhi

AT the outset, let me express my appreciation of the honour you have done me by electing me as President.

For this address I have decided to give an account of the wheat work with which I have been directly associated at the Indian Agricultural Research Institute from 1933. The previous work on this crop is well known and the earlier "Pusa" wheats evolved by the Howards are internationally known. The work was continued by F. J. F. Shaw, who was assisted by A. R. Khan and Kashi Ram, both of whom had formerly worked with the Howards. There are numerous publications giving the results of this earlier work on wheat. A convenient summary of this was published in the *Empire Journal of Experimental Agriculture* (Pal, 1944). The present account refers more particularly to the work done after the move of the Institute from Pusa to New Delhi in 1936.

SURVEY OF INDIAN WHEATS

The importance of crop collections for plant breeding work is well known. Although the Howards had made extensive collections of Indian wheats, these had not been maintained. The wheat collections had, therefore, to be built up again. In 1938, about 424 samples of wheat-grains were obtained from different parts of India and grown in the season of 1938–39. Practically all the samples were observed to be mixtures of many varieties, and the different pure lines were isolated mainly on the basis of differences of ear and grain characters. As a result of this and of the addition of a new collection in 1944, the total number of strains went up to 1091.

* Presidential Address read before the 30th Annual Meeting of the Indian Botanical Society held at Bangalore, on 1st of January, 1951.

These wheats were studied and classified according to the Provinces from which they were collected and according to the species and varieties.

Besides these varieties which were collected from the plains of India, a separate collection was made of wheats grown in the hills and mountains of India including Kashmir, the Simla Hills, the U.P. Hills, Western Ghats, and the Nilgiris. Material of mountain wheats was also obtained from Sikkim, Bhutan, the neighbouring regions of Tibet, Afghanistan, and Iran. The Afghanistan material included collections made by the German Expedition to Afghanistan in 1935 and is, therefore, particularly valuable. The hill wheat collections have for obvious reasons to be maintained at a station in the mountains and the collections have actually been grown and maintained at Simla. The study of this material has been taken up, in part, from time to time, as staff was available. But a complete study has not been possible up to now.

A recent development is that India has been asked to co-operate in the FAO Scheme for the maintenance of the world collection of genetic stocks and the publication of a world catalogue describing the varieties maintained. This work has been entrusted to the Indian Agricultural Research Institute and a start has been made, during the last season, with the detailed description of 100 important varieties of wheat grown in this country.

Collection of Exotic Wheats

Besides the Indian material a large number of wheats from foreign countries has been studied, especially with the object of discovering sources of rust resistance for use in the breeding work. This material has included the various naturally-occurring species of wheat, synthetic species of wheat such as *T. timococcum*, genera allied to wheat such as *Agropyron* and *Aegilops*, hybrids between wheat and related genera including wheat-*Agropyron* hybrids and wheat-rye hybrids, improved strains of wheat reputed to possess a high degree of rust resistance such as Hope and Thatcher wheats from America and Gabo, Ridley, Charter, and Warigo from Australia, Frondosa and Frontiera from South America, etc. These wheats have been studied in the open, in small plots, in the first instance, and the more promising material has been subjected to controlled rust inoculations. In this way, nearly 1,000 foreign wheats have been introduced and studied. Some of them, including the varieties E. 144 and E. 220 from Kenya, Gabo from Australia and Thatcher from America are being used in wheat breeding work not only at the Indian Agricultural Research Institute but at other wheat breeding centres in India.

Description and Registration of Commercially Important Varieties and Those of Special Interest to Our Plant Breeding

This work was taken up on the recommendation of the Standing Wheat Committee of the Indian Council of Agricultural Research

which at the instance of the speaker recommended that as in some other agriculturally-advanced countries, detailed descriptions should be recorded and published of every variety of commercial importance and also of those varieties which are of plant breeding interest. Under the scheme, whenever it is desired to add a fresh variety to the list it would be necessary to determine whether it could be distinctly differentiated from the previously registered varieties and whether it was superior to them in any respect. This would ensure the identification and elimination of duplicates for the registered varieties. Moreover, it would also ensure that no variety is distributed to the farmer before it is thoroughly tested.

The work on wheat registration was started with 24 of the older Pusa wheats.* Three years' data were collected and analysed. The characters used for the study and the descriptive terms used were those adopted by the Special Committee set up by the Indian Council of Agricultural Research to recommend a uniform nomenclature for the description of wheat varieties (Pal, *et al.*, 1941). A report was sent for publication (Pal, Murty and Khan, *in press*). It was proposed to continue the work with the newer Pusa wheats and with the wheats from the provinces. Since, however, this country is now participating in the FAO Scheme, as mentioned earlier, the registration of wheats on the previous basis has been discontinued.

Breeding for Rust Resistance

The work carried out by the Howards, and later by Shaw and their associates, had resulted in the production of high-yielding varieties possessing excellent grain qualities, but considerable scope existed for improvements in other respects, such as, disease resistance, drought resistance, and resistance to lodging. In particular, the problem of finding a solution for the heavy losses caused by the wheat rusts in India remained unsolved. It was felt that if wheat production in India was to be placed on a satisfactory basis it was necessary to breed varieties which would resist this malady and at the same time have the desired agronomical qualities necessary in a commercial wheat.

Keeping this object in view many exotic and most of the existing Indian varieties of commercial importance were subjected to resistance tests against all the known Indian physiologic races of the three rusts (black, yellow and brown) both in seedling and adult stages. This work was taken up in collaboration with the late Dr. K. C. Mehta of Agra. The results revealed that none of the varieties was completely resistant to all the races of the three rusts. This showed that work was immediately necessary to breed varieties that would prove of value to the farmer from this particular point of view. Strains separately resistant to the black, brown and yellow rusts were built up and subsequently a double cross (W. 375) was attempted at Simla with the

* The prefix 'Pusa' is applied to varieties of crop plants evolved at the I.A.R.I. The name Pusa was subsequently altered to 'Imperial Pusa' (abbreviated as I.P.) and still later to 'New Pusa'.

object of combining resistance to all the three rusts. A portion of the seeds of the resultant progeny was also sown at Delhi in later generations so that selection of plants suitable to the conditions prevailing in plains may be made side by side with the selection of plants for the hills. The material grown at Simla was artificially inoculated, both in seedling and adult stages, with a mixture of all the known Indian physiologic races of all the three rusts and the resistant plants were selected every year; the plants raised at Delhi were tested in the adult stage only.

It is pleasing to mention that in 1946–47, the crop-year characterised by a very severe rust epidemic, many plants were observed to show resistance to all the three rusts. Such plants, irrespective of other agronomical qualities and those showing slight susceptibility but of promise with regard to the latter, were taken for study in the ensuing seasons. It is expected that certain of these selections will yield highly rust-resistant strains of wheat.

The work just mentioned is intended primarily for the hill regions. Dr. K. C. Mehta had shown that the summer heat in the plains kills out the rust fungus and the crop is infected anew every year by inoculum which is carried down by the wind from the hill regions, where the rust fungus is able to oversummer. It was rather unfortunate that the breeding work was linked up with the idea that if wheat rust could be controlled in the hills either by stopping wheat cultivation and pulling out all self-sown plants of wheat or by growing resistant varieties there the plains would be saved from the attacks of the rusts. It has now become obvious that it will not be practicable to try and enforce such control measures over the extensive areas in the hills where wheat and barley (barley is a collateral host for the black and yellow rusts of wheat) are cultivated. Moreover, there are other considerations, such as the possible existence of other collateral hosts, like wild grasses, which complicates the situation. It is, therefore, necessary to evolve rust-resistant wheats in the plains also. Work on the latter lines was taken up later. Already new N.P. wheats bred by the speaker are available (Nos. 700 to 781), some of which possess a useful degree of resistance to one or two of the rusts. In fact, N.P. 737 when tested in the seedling stage has been reported to be resistant to all the Indian races of brown rust and some other wheats of this series are resistant or tolerant to rust. A reference will be made later to trials conducted with these wheats in various wheat-growing regions of India.

Inheritance of Resistance to Rust in Wheat

In the several crosses made for the study of the inheritance of resistance to the three individual rusts, *viz.*, black, brown, and yellow, consistent results were not obtained in those made for black and brown rusts, due probably to a number of different genes being responsible for the expression of this character with regard to the different physiologic races for each of these rusts. On the other hand the results of three crosses made for the study of resistance for all the

races of yellow rust indicate that the inheritance is monogenic and that susceptibility is dominant. The following table gives the F_2 results of the three 'yellow rust' crosses:

TABLE I

Cross	No. of seedlings		Total
	Susceptible	Resistant	
E. 4 × N.P. 120 ..	387	111	498
E. 69 × N.P. 114 ..	387	137	524
E. 68 × C. 518 ..	359	169	528
Total ..	1133	417	1550
expected 3 : 1 ..	1162	388	

OTHER GENETICAL STUDIES

During the course of genetical investigations in the interspecific crosses in *Triticum* some interesting observations were made. In the hexaploid group, crosses between *T. vavilovi* and other species, *viz.*, *T. vulgare* and *T. sphærococcum*, have been studied for various characters of the spike, especially in respect of 'branching' of the ear (a character possessed by *T. vavilovi*), 'extra glumes' (a new character not exhibited by the species used as parents but appearing in the progenies), and glume colour. In the case of 'branching', whereas the branched condition is recessive to the 'normal' condition in the first generation, the behaviour in the subsequent generations indicates that the inheritance of this character is of a complex nature. The 'branched' condition was also found to be closely linked with difficult threshing of grain so that amongst the progenies the combination of 'branching' and easy threshing was not found. The inheritance of the 'extra glume' character which was noticed in the F_2 progenies of crosses with *T. sphærococcum* and with certain varieties of *T. vulgare* was also observed to be complex. Whereas this character appeared in crosses with E. 113—an exotic awnless wheat—no such type appeared in the case of N.P. 114 and N.P. 165. It was also observed that the 'extra glumes' character was differentiated more clearly in F_3 and later generations. Taking into consideration the combinations of the two characters with other characters of the spike 23 distinct types have been isolated. In an attempt to find out basis for the interpretation of the appearance of these types and for the complex nature of the inheritance of these characters, cytological investigations have been taken up. The preliminary observations reveal that these types are chromosomal aberrants.

From amongst the various intergeneric crosses attempted, the cross *T. vulgare* × *Aegilops caudata* incidentally gave indication of the possible origin of the wheat species *T. sphærococcum*. In the F_4

and F_5 progenies of this cross, resulting from a solitary F_2 seed, there were noticed some plants resembling *T. sphærococcum* in general plant and ear characters. It is as yet not definitely known how such plants originated (Pal and Singh, unpublished).

Correlation Between Rust Resistance and Other Characters

As the establishment of a definite correlation between rust resistance and some simple morphological or functional character would obviously be of much value in breeding rust-resistant wheats, a study of such characters in relation to black rust resistance in a number of representative wheat rust varieties was undertaken at the Simla branch station.

Sixteen wheat varieties belonging to the species *T. vulgare*, *T. durum*, *T. dicoccum* and *T. monococcum* and including varieties highly resistant, moderately resistant and highly susceptible to stem rust, were studied in respect of the proportion of collenchyma in the peduncle region of the stem, the relative numbers of single and double collenchyma strands, and the size of the individual collenchyma strands. While all the susceptible varieties were found to possess a comparatively large proportion of collenchyma, the reverse did not hold true and some of the resistant varieties also had a large porportion of collenchyma.

The time of opening of the stomata in the morning and the duration of the period of opening were studied in 11 varieties out of the 16 referred to above, at two periods in winter and two periods in spring. While the time of opening of stomata was found, within limits, to be a varietal characteristic, no correlation was discovered between this character and the rust reactions of the varieties studied.

It was concluded that none of the characters studied furnishes an index for facilitating the breeding of rust-resistant strains of wheat (Pal and Hasanain, 1946).

Resistance to Loose Smut

Although hot-water treatment of seeds immediately before sowing and its variant, the solar heat treatment, have proved to be an effective method of protecting the resulting crop from the attack of loose smut *Ustilago tritici*, it does not prevent further infection. Thus it involves inconvenience every year to the cultivator and also a certain amount of expense. Since it is now an established fact that resistance or susceptibility to certain diseases is an inherited character, it becomes necessary to know which of the varieties can resist this disease, and consequently provide valuable material to the breeder.

Many varieties, both foreign and indigenous, have been tested, from time to time, in collaboration with the Mycology Division of this Institute. The results have been published (Mundkur and Pal, 1941; Pal and Mundkur, 1945). In these tests it was revealed that N.P. 114 is practically immune to loose smut and N.P. 165 and N.P. 120 are highly resistant.

In later tests, some of the new N.P. wheats (700 series) were tested and several of them have been found to be immune or highly resistant.

Resistance to Flag Smut

This disease is serious only in north-west India. The varieties that were tested for resistance to loose smut were also tested for resistance to flag smut with the co-operation of the Mycology Division of the Institute. Several varieties were found to be resistant, but unfortunately those that were resistant to loose smut were usually susceptible to flag smut and *vice versa* (Pal and Mundkur, 1941).

Studies on Leaf Hairs as a Possible Aid in Classification

The classification of cultivated varieties of crop plants necessitates recourse to some plant characters, ordinarily not used by the classical taxonomists, in view of the bewildering multitude of forms which are nearly related and yet may differ sufficiently physiologically to render their correct identification a matter of very great interest to the agriculturist and the plant-breeder. As has been pointed out by Percival (1921), Vavilov (1939) and the speaker (Pal, *et al.*, 1941) the characters of the ear, generally used in varietal classification are too wide to allow of such type-identification and some character of the vegetative parts, preferably discernible early in the life of the plant, such as leaf-pubescence, has to be evaluated as a classificatory aid. With this object, work was started at the Indian Agricultural Research Institute to evaluate the utility of the leaf-hairs in the classification of the species and varieties of *Triticum*.

In order to get a comprehensive idea of the type and degree of variation exhibited by the character it was thought desirable to study as diverse a material as possible. In addition to representatives of all the species (chosen from the collections maintained at the Indian Agricultural Research Institute) and some allied genera, about 20 varieties cultivated in the plains, and some 25 varieties from the hill collection at Simla were studied. In addition some 15 types from Afghanistan, the centre of origin of *vulgare* wheats (according to Vavilov and Bukinich) were included to get as much genetically-varied material as possible. A preliminary attempt to test the stability of the character under different environmental conditions was also made by carrying out sowing at different dates and by subjecting some types of long-day conditions. The hairiness was examined under the microscope by peeling the leaf-epidermis after maceration. Sheath and auricle hairiness were also recorded.

As the utility of any character as a taxonomic criterion may be said to depend first and foremost on the existence of sufficient and discontinuous variation, the character under consideration was examined from this view-point and the variation found to exist could be conveniently classified under the following headings:

(1) *Arrangement.*—Three major types could be differentiated according as to whether the hairs were present on the ridges (crest of

the ribs) only, on the flanks only or on the ridges and the flanks of the leaf-epidermis.

(2) *Types of hair.*—Based on the length, 3 types of hairs could be easily recognised, the long, the short and the spine-like hairs.

(3) *Density.*—While considerable variation existed and a number of grades such as dense, medium and sparse could be differentiated based on the number of hairs per unit area, the continuous variation presented made it necessary to delimit these classes on the basis of arbitrarily selected class-values.

(4) *Length.*—Here again the variation existent was considerable but continuous and hence necessitated the use of arbitrary class-limits such as over 750, 500–750, etc.

The variation exhibited in breadth, shape or direction of the hairs was not wide nor consistent enough to permit of their use as classificatory aids.

The variation existing in the sheath hair character was less extensive than in leaf hairs and only a few broad classes could be formed. While the absence or presence and the extent of leaf margin hairs and the hairy or glabrous nature of the auricle could be used to carry the differentiation further, sheath margin hairiness was not so useful.

Based on the types of variation indicated above and using the various combinations of upper and lower epidermal hairiness and sheath and leaf margin hairiness it was found possible to construct a skeletal classification and distinguish the varieties taken up for study.

The preliminary experiments undertaken seemed to indicate that the character of leaf-hairiness was not markedly affected by external environmental conditions.

It may thus be seen that the character of the leaf-pubescence can be used in distinguishing the varieties of *Triticum*, for sufficient variation exists in its different aspects; it is controlled genetically in a simple manner, so that discontinuous variation, the essential prerequisite of any classificatory character, is present; and it does not seem to be liable to any marked environmental variation nor does it seem to be of an adaptive character. Though some intra-varietal variation does exist and it may be necessary to assess whether this is hereditary or due to mechanical mixture and appreciation of the character, involving as it does the use of the microscope, it is likely to prove useful as one of the characters in classifying the cultivated varieties of wheat. However, detailed study on the effect of the environment on the character would seem essential before a workable scheme using this character could be drawn up, applicable at least to the varieties grown in a particular geographical area, even if it does not hold good all over the world (Pal, Ramanujam and Memon, unpublished).

Natural Crossing in Wheat

The occurrence of natural cross pollination in cultivated crops is of importance to the breeder and to the farmer as it has an adverse influence upon the general purity of seed stocks. It was considered desirable to determine the extent of natural cross pollination in this crop under Delhi conditions. Three wheat varieties, namely, N.P. 4, N.P. 52 and N.P. 120 were selected for this study as these varieties possess well-marked differential characters and it is relatively easy to detect in the field the naturally-occurring F_1 hybrids between these varieties. The experiment was initiated in 1944–45.

The results of this experiment are indicated in the following table:

Year	Percentage of natural crossing in			Totai percentage
	N.P. 4	N.P. 52	N.P. 120	
1944-45 ..	Nil	Nil	Nil	Nil
1945-46 ..	0·28	0·06	0·54	0·29
1946-47 ..	0·37	0·31	0·65	0·44

On the whole the percentage of natural crossing in wheat seems to be low under Delhi conditions and it should not be difficult to maintain the purity of the crop by occasional roguing (Pal, Deshmukh and Memon, unpublished).

Effects of Natural Selection in a Mixture of Wheat Species

The experiment was commenced in 1943–44 to see as to how different varieties belonging to different species of *Triticum* behaved in competition, when grown in a mixed population. The factors contributing towards the superiority of one species over the other were also sought to be studied.

Twenty grains each of fourteen varieties belonging to eleven species (*vide* Table II) were mixed up and grown in a small plot. The number of plants that survived in each variety were counted and the harvested seed was grown in a larger plot next season. Sowings in the subsequent years were done from the seeds obtained from the harvest of the previous seasons. Every year the plot was harvested after leaving out 5–6 sample plots. Population determinations were done on the sample plots each $6' \times 6'$ in size and marked at random. The study was continued up to the fifth generation. The trend of changes in the proportions of the different varieties is shown in the table below:

TABLE II

*The trend of changes in the proportions of different species in the population, in five generations, from 1943 up to 1949**

Species	Variety	% Grains Original (1943)	Percentage plants					% Grain 1949
			1943–44	1944–45	1945–46	1946–47	1948–49	
T. vulgare ..	N.P. 4	7·1	7·5	21·1	..	81·1	84·7	94·4
	N.P. 114	7·1	9·5	18·7	..	5·4	5·3	2·9
T. sphærococcum ..	E. 14	7·1	7·5	7·9	..	3·6	3·1	1·13
T. pyramidale ..	E. 228	7·1	8·0	10·2	..	5·6	4·0	1·15
	E. 229	7·1	6·8	15·2	..	2·5	0·5	0·20
T. persicum ..	E. 18	7·1	6·8	10·5	..	1·6	0·5	0·14
T. durum ..	E. 40	7·1	10·2	8·8	..	0·0	0	0
	E. 16	7·1	10·2	4·7	..	0	0	0
T. polonicum ..	E. 17	7·1	8·0	0·6	..	0	0	0
T. dicoccum ..	E. 56	7·1	1·4	2·3	..	0	0	0
T. dicoccoides ..	E. 303	7·1	3·4	0	..	0	0	0
T. timopheevi ..	E. 79	7·1	9·5	0	..	0	0	0
T. monococcum ..	E. 25	7·1	6·0	0	..	0	0	0
T. ægilopoides ..	E. 302	7·1	4·8	0	..	0	0	0
†*T. vulgare* Varietal hybrids	I, II, III, IV	0	0	0	..	0·4	1·7	0·98

* No sowing was done in the 1947–48 season and no observations were taken in the 1945–46 season.

† Two ears belonging to a plant suspected to be a natural cross between N.P. 4 and N.P. 114 were sown in pots next season and segregation for the characters of the two varieties was observed.

Table II clearly indicates that the *vulgare* species has dominated almost completely over the others, and within the *vulgare* group N.P. 4 has dominated over N.P. 114. Observations recorded on inter-varietal mixtures and hybrid generations in another study had shown that elimination of varieties under inter-varietal competition is a long-term process and may not lead to the complete elimination of any variety. The above observations (Table II), however, indicate that the process of elimination is quicker and more or less complete in the case of inter-specific competition.

Observations on the grain production at the end of the first season showed that varieties of the species *T. dicoccoides*, *T. timopheevi*, *T. monococcum* and *T. ægilopoides* set no grains under the experimental conditions at Delhi.

The following general conclusions could be tentatively drawn from this study:—

(*a*) In species competition, elimination of the species is faster than that of varieties in inter-varietal competition.

(*b*) Both the components of productivity, *i.e.*, number of ears per plant and the number of grains set per ear vary considerably, the former being especially important.

(*c*) Selective mortality between different varieties and species may exist.

It would appear that all these factors have contributed towards the better performance of N.P. 4, *T. vulgare*, over the others under Delhi conditions (Pal, Khan and Upadhaya, unpublished).

Vernalization Experiments

The effect on flowering of pre-sowing temperature treatment as well as day length was studied in different varieties of wheat at Delhi and Simla. Five varieties of wheat, three English winter wheats, *viz.*, Cambridge Rivett, Yeomen II and Joss 4, which are late under Delhi conditions and two Indian wheats, *viz.*, N.P. 165 and N.P. 14 were used.

Cambridge Rivett flowered earlier by 5 days at Delhi as a result of vernalization of 2° C., whereas Indian wheats showed no response. At Simla the response was very slight. Chilling of seeds for 4 weeks combined with long-day treatment of the plants induced earliness by 8 weeks in Cambridge Rivett. In Indian wheats, earliness was induced by long-day alone and was delayed by short day (Pal and Murty, 1941).

Experiments on the effect of vernalization were continued in collaboration with Mr. B. Sen of Almora. Varieties of wheat from different parts of India were studied both at Delhi and Almora. The range of earliness in flowering varied from 10 to 29 days. On the whole flowering was slightly earlier at Delhi than at Almora and this difference can be attributed to the relatively high temperature at Delhi during the growth period (B. Sen, *et al.*, 1946).

Performance Tests of Recently-Evolved Pusa Wheats in Different Wheat-Growing Regions

The yield trial of some recently-evolved N.P. strains of wheat is being conducted since 1946–47 at over 20 stations representing the different wheat-growing areas of the country, in order to determine the suitability of these strains for different areas. The results of trials conducted at six important stations are given in Table III. The order of merit of the strains has not been the same in the different years, but even then it is possible to indicate strains suitable for different areas.

Karnal.—N.P. 710, 718, 720, 760, and 775 have given good yields of grain. N.P. 718 and 775 appear to be particularly suitable for the area.

Delhi (*I.A.R.I.*).—N.P. 710, 718, 760, and 775 have given better yields than others and are therefore suitable for the Delhi area.

Nagina.—N.P. 710, 720, 737, 761, and 775 have fared quite well. Certain of these have given much higher yields of grain than the

TABLE III

Results of yield trials of new wheat strains at 6 centres

Order of Merit	Punjab (1)				Delhi				U. P. (West)				U. P. (Central)				Bihar				Bombay	
	Karnal				I.A.R.I				Nagina				Kanpur				B.S.S. Pusa				Kopergaon	
	1946-47	1947-48	1948-49	1949-50	1946-47	1947-48	1948-49	1949-50	1946-47	1947-48	1948-49	1949-50	1946-47	1947-48	1948-49	1949-50	1946-47	1947-48	1948-49	1949-50	1948-49	1949-50
1st ..	—	775	718	*C.518*	775	*C.518*	760	760	710	720	775	720	710	720	710	710	764	745	762	710	710	760
	**	1115	1626	1783	1878	1681	1898	1937	1274	1423	1959	1609	1907	2575	2131	1407	877	877	844	937	545	2978
2nd ..	—	720	760	C.591	710	758	165	764	720	761	737	775	715	733	758	718	758	710	764	737	715	715
	**	1025	1626	1651	1811	1621	1875	1905	1260	1395	1830	1567	1822	2518	2131	1369		855	791	918	518	2850
3rd ..	—	761	775	775	715	761	710	*C.591*	775	775	745	*C.13*	733	710	762	758	762	760	775	718	764	710
	**	935	1596	1517	1618	1590	1845	1904	1259	1251	1715	1549	1726	2476	2084	1320		839	784	907	458	2790
4th ..	—	737	715	718	720	718	715	710	*C 13*	722	720	737	*C.13*	775	760	737	*52*	720	*52*	760	718	*N.-4*
	**	910	1554	1475	1593	1564	1799	1873	1098	1135	1681	1456	1689	2337	2032	1286		831	777	859	451	2748
5th ..	—	C 518	710	710	733	762	718	775	722	*C.13*	*C.13*	718	775	715	720	C.13	760	761	Local	720	760	720
	**	895	1542	1470	1560	1564	1777	1858	1059	1105	1609	1382	1686	2310	2021	1282		733	717	850	436	2550
6th ..	—	710	*C.591*	760	773	775	775	718	733	710	761	710	720	773	775	715	737	734	758	52	*N.-4*	718
	**	880	1524	1444	1503	1547	1656	1772	1023	1048	1597	1366	1531	2276	1928	1267		719	717	840	434	2520
7th ..	—	715	C.518	720	*C 591*	710	*C.591*	720	715	758	758	761	773	722	737	760	766	762	745	715	758	775
	**	820	1518	1412	1494	1526	1656	1750	945	1024	1548	1308	1342	2161	1917	1267		695	697	835	423	2445
8th ..	—	758	737	715	121	715	737	762	773	121	718	758	121	*C.13*	764	764	761	*52*	715	745	762	764
	**	785	1464	1395	1379	1474	1648	1746	871	970	1461	1253	1324	2153	1899	1237		683	690	802	394	2441
9th ..	—	764	720	737	722	720	720	165	723	715	762	755	722	121	715	761	741	715	718	761	761	762
	**	600	1446	1358	1290	1460	1625	1724	807	945	1369	1172	1252	2039	1893	1230		678	683	784	362	2321
10th ..	—	760	745	761	723	P.C.36	761	715	121	773	710	715	723	723	718	762	755	737	737	762	4	758
	**	590	1410	1358	1215	1344	1618	1668	804	911	1363	1148	1137	1836	1888	1135		676	663	733	352	2220
11th ..	—		761	745	768	760	762	758	769	733	755	745	768	770	*C.13*	755	779	758	761	Local	775	761
	**		1356	1300	1182	1340	1565	1639	725	830	1085	1133	1021	1830	1783	1132		639	616	718	307	2134
12th ..	—		758	758	770	764	758	737	770	764	715	762	770	768	775	745	745	779	720	764	745	Local
	**		1329	1269	916	1292	1557	1624	544	483	968	960	850	1709	1714	1015		472	616	697	298	2058
13th ..	—		762	762			745	761			764	764			761				760	758	737	745
			**1242	1253			1542	1499			781	816			1453				516	677	278	1835
14th ..	—		764	764			764	745			760	760			745				710	775	Local	737
			**1116	1157			1504	1376			666	586			1338				452	599	234	1808
15th ..			—	—																		

Figures in the lines beginning with ** indicate the yield of grain in lbs. per acre.

— (underline) indicates higher yielding control.

control in some seasons. N.P. 775 has done consistently better than the check variety.

Kanpur.—N.P. 710, 715, 737, 720, and 758 have proved better yielders than the standard variety Kanpur 13 at this centre. N.P. 710 is outstandingly good here.

Pusa.—N.P. 710, 745, 760, 762, and 764 have given good yields of grain. For Bihar as a whole, N.P. 761, a very early maturing strain, is also promising.

Kopargaon.—N.P. 710, 715, and 760 have done better than the controls in both the years.

Taking the results at all the centres (including those not mentioned above) N.P. 710 has shown a remarkable degree of adaptability under a wide range of conditions.

This brief review of wheat work does not include the very interesting physiological investigations being carried out on wheat in the Division of Botany by Dr. R. D. Asana and his associates, or the cytological investigations started comparatively recently under the leadership of Dr. P. N. Bhaduri.

LITERATURE CITED

MUNDKUR, B. B. AND PAL, B. P. 1941. Studies in Indian cereal smuts. II. Varietal resistance of Indian and other wheats to loose smut. Indian J. Agric. Sci. 11: 675–686.

PAL, B. P. AND MEMBERS OF A SPECIAL SUB-COMMITTEE. 1941. The description of crop-plant characters and their ranges of variation. III. The variability of Indian wheats. Indian J. Agric. Sci. 11: 479–492.

——— AND MUNDKUR, B. B. 1941. Studies in Indian cereal smuts. III. Varietal resistance of Indian and other wheats to flag-smut. Indian J. Agric. Sci. 11: 687–694.

——— AND MURTY, G. S. 1941. Studies in the vernalization of Indian crop plants. I. Preliminary experiments on gram, wheat, chilli and soybean. Indian J. Genet. & Pl. Br. 1: 61–86.

PAL, B. P. 1944. The Pusa wheats : The wheat-breeding work of the Imperial Agricultural Research Institute. Empire J. Exptl. Agric. 12: 61–73.

——— AND MUNDKUR, B. B. 1945. Studies in Indian cereal smuts. VII. Further studies in varietal resistance of Indian and other wheats to loose smut. Indian J. Agric. Sci. 15: 106–108.

——— AND HASANAIN, S. Z. 1946. A study of the relation of certain morphological and functional characters to the stem rust resistance of wheat varieties. Indian J. Agric. Sci. 16 : 459–468.

———, MURTY, G. S. AND KHAN, H. B. Registration of Indian wheat varieties. Indian J. Agric. Sci. (in press).

PERCIVAL, J. 1921. The Wheat Plant, a monograph. London.

SEN, B., CHAKRAVARTI, S. C., PAL, B. P. AND MURTY, G. S. 1946. Vernalization response of cultivated Indian wheat. Curr. Sci. 15: 351–352.

VAVILOV, N. I. 1923. A contribution to the classification of soft wheats. *Triticum vulgare* Vill. Bull. Appl. Bot. Leningrad. 13: 149–257. (Extended Summary by the Imperial Bureau of Plant Breeding and Genetics). Original not seen.