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The prevention of pre-harvest sprouting

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Section I

A. Executive Summary

Pre-harvest sprouting (PHS), the germination of cereal grain on the mother plants before harvesting, affects the economical value of the harvest since germinated young seeds can be used. at a much lower price than grain for flour, for animal feeding. The phenomenon is due to the lack of ABA in the young seeds and/or their insensitivity to the dormancy-inducing hormone. We have observed an easily determinable parameter indicative of genetic PHS tolerance – the presence of an endosperm factor, presumably ABA, capable of inhibiting nitrate reductase induction in the embryo in the presence of NO_3^-. This finding has importance not only for the early rapid screening of PHS-tolerant cultivars but may also be an important tool to determine the mechanism of NR inhibition either by genetic repression or by post-translational down regulation of NR activity which is one of the characteristics of plants exposed to environmental stresses such as drought and salinity.

Further work will continue with the PHS tolerant and sensitive~~s~~ wheat cultivars kindly provided by the N. Baraev Cereal Research Institute in Shortandy (Kazakhstan) which will focus on agrotechniques designed to minimize PHS in the field, and on studies to determine the genetic, physiological and biochemical mechanisms which determine the lack of dormancy and the propensity to germinate before harvesting. During the firsts months of 2003, a postdoctoral fellow from the Astana University will work at the Sede Boqer laboratories with the Israeli investigators, seeking mechanisms which determine either a block of ABA (the seed dormancy induction factor) synthesis or the insensitivity to ABA signals in the seed genetic makeup. At the same time that PHS tolerant cultivars will be screened and developed, efforts to devise simple agrotechniques to overcome PHS sensitivity under field conditions will be continued.

B. Research objectives

Overall aim

To prevent pre-harvest sprouting of wheat seeds through the increase of ABA synthesis in the seeds and to accelerate wheat growth rate, thus allowing early grain maturation before the onset of the rain season in Kazakhstan.

Scientific Objectives:

(1) To prevent pre-harvest sprouting of cereal crops by seed pretreatments before sowing as well as treatment of developing plants in the field.

(2) Optimization of seed treatments which improve cereal productivity by preventing pre-harvest sprouting: (a) Alternating hydration and dehydration treatments; (b) Seed hydration in the presence of essential trace and macroelements such as molybdenum and nitrate; (c) Seed wrapping in gels containing Mo and NPK.

(3) Studies of Mo transport from pretreated seeds, initially to the new roots and leaves and later to developing seeds that require Mo to produce aldehyde oxidase and the subsequent synthesis of ABA required to establish seed dormancy. Studies of the activation of leaf and seed Mo-enzymes by molybdenum of the pretreated seeds.

(4) Test the new treatments under field conditions.

C. Research Accomplishments

This project began in practical terms about 4 months ago. The following are results of a joint experimental line set up in Sede Boqer by Z. Alikulov and followed later in Astana. Work on the inhibition mechanism of ABA induction or its post-translational down regulation are continuing now by H. Lips.

Early metabolic markers of preharvest (PHS) sensitivity

Experiments to determine the activities of Mo-enzymes as early markers of PHS were carried out in PHS tolerant (Lutescence 70) and sensitive (Novosibirskaia 67) wheat varieties during seed germination. NR (nitrate reductase) activity was determined in the aleurone layers, endosperms and embryos. Dry seeds, not showing any detectable NR activity were incubated in distilled for 24 h, after which only the embryo showed negligible NR activity. NR activity developed in seed embryos only after incubation in the presence of KNO_3 and its levels depended on the wheat varieties (Table I).

Table I. NR (nitrate reductase) and NiR (nitrite reductase) activities in attached and detached embryos of PHS tolerant and sensitive wheat seeds. Enzyme activity given as nanomoles of nitrite or ammonium produced embryo^{-1} h^{-1}.

	PHS-tolerant Lutescence 70				PHS-sensitive Novosibirskaia 67			
Incubation time (h)	Attached embryos		Detached embryos		Attached embryos		Detached embryos	
	NR	NiR	NR	NiR	NR	NiR	NR	NiR
12	0.0	8.5	4.3	22.5	0.7	17.6	5.2	23.7
16	0.0	10.3	3.5	22.0	1.2	18.7	5.0	21.4
20	0.0	15.5	2.7	18.6	2.4	21.8	4.3	18.0

In the embryos present in the intact seed there was no NR activity until 24 h of incubation. It appears that the presence of endosperm in the intact seed inhibited the induction of NR in the

embryos during the (first 24 h) germination of the PHS-tolerant wheat seeds but not in the embryos of the PHS-sensitive wheat seeds. Thus, only the endosperm of PHS-tolerant seed appeared to inhibit NR induction. Other enzymes of nitrate assimilation pathway, such as nitrite reductase, NiR, (Table I), glutamine synthase and glutamate dehydrogenase were also found to be present in *in situ* embryos during the initial stages of germination in wheat (Gilmanov et al., 1988). Thus, it appears that among the key enzymes of nitrate assimilation only NR shows a long lag period in its development that seems to be exerted by the endosperm of PHS-sensitive seeds for NR.

The level of the inhibitory endosperm factor of PHS-sensitive wheat seeds appears to be lower in PHS-tolerant seeds. The inhibitory factor gradually disappears with seed aging, similarly to the fate of the dormancy controlling ABA, the level of which determines the PHS sensitivity of the seeds, suggesting that ABA may regulate the synthesis of NR in wheat embryos and perhaps in other plant tissues. These observations are significant in view of the fact that NR inducion in wheat seed embryos correlates with their level of PHS tolerance. Thus, the 4-6 h inhibition by the endosperm extract of NR in detached embryos may serve as a marker of the PHS tolerance of wheat seeds, and may be used as an early parameter for fast genetic screening .

Molybdoenzymes in developing and maturing seeds of PHS-tolerant wheat

It was found in preliminary experiments that dormant dry seeds of wheat and barley contain activ molybdenum cofactor (MoCo), an essential component of the active center of molybdenum containin enzymes (Mo-enzymes). Chromatographic studies showed that in the crude extract of wheat seed MoCo is tightly bound to high- (300 kDa) and low-molecular weight (65 kDa) proteins. The firs turned out to be xanthine dehydrogenase (XDH) and aldehyde oxidase (AO). the activity of nitrat reductase (NR) was not detected in the high molecular weight fraction. Cell free extract of dorman seeds did not cross-react with polyclonal antibodies raised against NR of barley. The study of lov molecular weight MoCo-containing proteins is still in progress.

The distribution of Mo-enzymes in different parts of wheat seed was carried out as part of the stud of pre-harvest sprouting in wheat seeds, including their dynamic changes during seed development an maturation. For the study we used wheat seeds of the pre-harvest tolerant cultivars **Lutescence 7** (PHS), obtained from the N. Baraev Cereal Research Institute in Shortandy (Kazakhstan).
MoCo content and Mo-enzyme activities in the parts of dry wheat seeds. MoCo content was highest in th embryo and aleurone layer while negligible in the endosperm of dormant seed. The embryo and aleuron layer extracts contained also XDH and AO activities (Table I). Mo-enzymes were not detected in th endosperm, in accordance with the lack of MoCo observed in this tissue (Table I). A single AO band wa found in the embryo and aleurone (not shown). According to the results reported (Seo et al., 1998 Omarov et al., 1998) AO showed the highest activity with indole-3-aldehyde followed by acetaldehyde Early results (Alikulov and Schieman, 1985) showed that NR-antibodies did not cross-react with protein of extracts of wheat seed embryos, endosperm and seed coats. NR activity was not observed in the extrac of dormant seeds when NAD(P)H, FADH or MVH was used as electron donors.

Table I. Activities of MoCo, AO, XDH and NR in different seed parts of PHS-tolerant cultivar Lutescence 70.

Seed part	MoCo[1]	AO[2]	XDH[3]	NR[4]
Embryo	16.7	75	1.5	0.0
Aleurone layer	10.5	55	1.2	0.0
Endosperm	0.5	0.0	0.0	0.0

[1] μmol NO^-_2 formed by nit-1 NR mg-1 protein hour-1;
[2] nmol DCIP mg-1 protein min-1;
[2] μmol NADH mg-1 hour-1; [4] μmol NO^-_2 mg-1 protein hour-1.

MoCo and Mo-enzymes in developing and mature seeds. The content of MoCo and the activities of NR XDH and AO in developing seeds were determined at five days intervals starting from10 DPA (Table II) Water content of the seed attained a peak at 25 DPA and then started declining to its lowest level a maturity. A linear increase in fresh as well as dry matter of the seed was observed between 10 and 3 DPA. The activity of MoCo in embryos and aleurone layers was low on 10 DPA. A slow increase o

MoCo occurred in these seed parts after 15 DPA and the synthesis of the cofactor intensified at 30 DPA reaching a maximum at 40 DPA (Table II).

Low AO activity was detected in the embryo and aleurone layer of seeds until the age of 30 DPA. After this age the activity of the enzyme in the embryo increased steeply reaching a maximum at 40 DPA, the enzyme activity in the aleurone layer increased slightly. Thus, the increase of AO activity in the embryo followed the pattern observed in MoCo activity in the embryo. Therefater, AO activity in the embryo fell significantly at full maturity of the seeds, while AO activity in the aleurone layer remained at a steady level (Table II). Our results in good accordance with the data obtained by Kawakami et al. (1997), where ABA, a product of AO, also started to increase at 30 DPA and reached maximum at 40 DPA in embryos of wheat resistant to pre-harvest sprouting.

Table II. Dynamics of MoCo-, AO-, XDH- and NR activities in the embryo of wheat seeds during their development and maturation

DPA	MoCo	AO	XDH	NR*
10**	5.3	10.2	1.6	0.0
15**	8.5	11.0	1.7	0.0
20**	9.2	11.8	1.5	0.0
25**	10.7	15.6	1.9	0.0
30**	13.5	18.3	1.7	0.0
35	16.3	37.8	1.6	0.0
40	17.5	67.4	1.8	0.3
45	17.3	66.8	1.8	1.8
50	17.6	65.5	1.9	2.5
55	17.1	66.7	1.7	4.8
Full maturity	17.0	67.5	1.8	5.0

* Developing seeds were detached from ears and incubated in 60 mM KNO_3 for 30 h and in their extract NADH-NR activity was determined

**The activities were determined in embryonic parts of developing seeds (see Materials and Methods).

Based on the similarity of animal and plant AOs, plant enzyme may also produce ROS during the conversion of ABAld into ABA. Furthermore, another key enzyme in ABA biosynthesis 9-cis-Epoxycarotenoid Dioxygenase which converts violoxanthin and neoxanthin to xanthoxin also produces superoxide anion (Schwartz et al., 1997; Qin and Zeevaart, 2002). Thus, increased ABA-synthesis during natural dehydration of wheat seeds may result in increased ROS production in the embryo. Our results show that an increased synthesis of ABA in seeds during their maturation leading to generation of ROS feasible.

From the early stages of development the seeds showed well detectable levels of antioxidants. The levels of water soluble antioxidants were significantly higher than toluene-soluble ones. When the seeds entered to the dehydration, the levels of antioxidants started to increase, and sharp increase of antioxidant levels was parallel with the increase of AO activity. Water soluble antioxidants increased 3-3.5 times while toluene-soluble antioxidant level only 2 times. Like ureides, the antioxidants reached a maximum levels at 40 DPA (Table III), and then lipophilic antioxidants remained at a constant level until full seed maturation, while water soluble ones slightly decreased. Like ureides, antioxidant level in the embryo of developing seeds was higher than that in aleurone layer, the ratio of total antioxidant content (water soluble + lipophilic) in the embryo to the aleurone layer in 10-35 DPA interval was 2 : 1, while after 35 DPA during seed dehydration it was 6 : 1. From 50 DPA stage of seed development and until full seed maturity the ratio of total antioxidant levels of the embryo to the aleurone layer changed and it was 3 : 1.

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Table III. Total content of ureides and antioxidants in the embryo of developing and maturing wheat seeds

DPA	Allantoin*	Total antioxidants**
10	480	11.5
15	510	10.9
20	515	12.0
25	525	13.0
30	720	15.2
35	2150	32.7
40	2320	55.4
45	2300	55.2
50	2370	54.0
55	2335	55.2
Full maturity	2230	53.8

*nmol g-1 seed DW; **µg/g embryo DW

XDH activity in the aleurone layer of developing seeds was significantly lower than in embryo part. Sinc ureides such as allantoin and allantoic acid are products of purine catabolism in which XDH plays a ke role, estimates of the XDH activity and allantoin content were made in tandem throughout the see development. XDH activity remained at a fairly constant level until full maturity, but the content of ureide increases 4.5 fold around 35-40 DPA, corresponding to sharp increase in AO activity (Table II). Ureide reached a maximum at this age, remaining thereafter at a constant level until full maturation. Throughou seed development the content of ureides was much higher in the embryo than that in the aleurone laye during seed dehydration their content in the embryo was 5 times higher than in aleurone layer. Thus XDH activity during seed development remained at a steady considerable high level while the increase formation of ureides followed the pattern of AO activity increase (Tables II and III). We propose that th main function of seed XDH is the production of uric acid to control the oxidative stress occurred durin seed dehydration.

Drought tolerance of the seeds during their dehydration may be improved an increased supply o endogenous antioxidants. The major soluble antioxidants in plant cell are water-soluble ascorbic acid an glutathione, and the lipophilic carotenoids alpha-tocopherol and flavonoids. Uric acid, a product of XDH is oxidized in the cells to allantoin by the enzyme uricase, and also non-enzymatically as potentia antioxidant by ROS (Santos et al., 1999). Uric acid was recognized to be a strong water soluble RO scavenger and significantly protects against strongest oxidant, peroxynitrite (Alamillo and Garcia-Olmed 2001), whereas ascorbate and glutathione are protective at concentrations exceeding those of uric ac (Pietraforte and Minetti, 1997). Thus, uric acid more effectively protects from ROS attack and removes th oxidative stress. Various environmental stresses result in an accumulation of allantoin in plant tissue Catabolism of hypoxanthine in maize root tips was accelerated more than 3.5-fold by salt stress (Peterso et al., 1988) or the stress resulted in an accumulation of allantoin in tissue culture (Akatsu et al., 1996 showing an increased conversion of uric acid into allantoin. On the basis of these results we conclude tha the main function of plant XDH is the production of uric acid which plays an important role in th scavenging of ROS.

Effects of foliar fertilization with molybdate or tungstate on Mo-enzyme activities.

Modi and Cairns (1994) showed that foliar fertilization of wheat plants with molybdate resulted i increased formation of ABA and, thus, prevents pre-harvest sprouting of the seeds. We studied the effect of foliar fertilization of flag leaves with molybdate and tungstate on Mo-enzyme activities during see development and maturation. Foliar treatments were described in Materials and Methods. Results of thes experiments are shown in Table IV.

Table IV. Effects of Mo- and W-treatments on the changes of MoCo-, AO-, XDH- and NR activities in the embryo of wheat seeds during their development and maturation

(Determinations as in Table II)

DPA	MoCo		AO		XDH		NR	
	+Mo	+W	+Mo	+W	+Mo	+W	+Mo	+W
10	5.0	5.2	10.5	10.0	1.5	1.6	0.0	0.0
15	8.0	8.4	11.5	11.3	1.7	1.5	0.0	0.0
20	11.4	10.9	12.0	10.2	1.7	1.6	0.0	0.0
25	11.7	11.2	17.2	9.3	1.6	1.3	0.0	0.0
30	15.5	14.5	20.5	7.7	2.2	1.3	0.0	0.0
35	18.8	19.3	41.4	6.8	2.0	1.0	0.0	0.0
40	20.5	20.7	74.2	6.5	2.3	0.8	0.5	0.0
45	22.6	23.6	75.6	6.5	2.5	0.8	2.5	0.0
50	24.8	24.4	74.8	6.7	2.4	0.9	6.5	0.0
55	24.5	24.0	74.5	6.3	2.5	1.0	8.0	0.0

Foliar fertilization of flag leaves with molybdate considerably increased the activities of MoCo. AO and NR. However, XDH activity increased only slightly. It is probable that, once synthesized, XDH molecules last a long period of time, i.e. only newly synthesized enzyme molecules may include the metal. AO and NR are more sensitive to exogenous molybdenum or tungsten levels. MoCo activities in seed embryos of plants treated with Mo and W were the same because *in vitro* MoCo activity using nit-1 extract was determined in the presence of exogenous molybdate. The results show that in presence of tungstate normal amount of MoCo is synthesized in the embryo, i.e. tungsten does not inhibit MoCo synthesis. Thus, we conclude that foliar fertilization of flag leaves may increase AO activity, and as its result also ABA levels.

Our preliminary results showed that PHS-tolerant and –sensitive seeds have different levels of antioxidants and ureides at mature stage. These investigations are presently in progress. Changes in the activities of MoCo, AO, XDH and NR are being studied comparatively in PHS-tolerant and sensitive wheat cultivars during seed development and maturation. Effects of presowing seed priming with different germination-stimulating compounds are also studying in both PHS-tolerant and –sensitive wheat cultivars.

NR activity in germinating seeds of PHS-tolerant and sensitive wheat cultivars

The following experiments were carried out to study the activities of NR in pre-harvest sprouting (PHS) tolerant and sensitive wheat varieties during their germination. Wheat seeds of the PSH-tolerant variety **Lutescence 70** and the PSH-sensitive variety **Novosibirskaia 67** were obtained from the N. Baraev Cereal Research Institute at Shortandy.

NR activity was determined in different parts of the seeds. The seeds were separated into aleurone layer, endosperm and embryo. These parts of dry seeds showed no detectable NR activity. Seeds were incubated in distilled water for 24-30 h, then separated and into their parts to determine NR activity in each of the tissues. Only embryos showed negligible NR activity. NR activity appeared in seed embryo only after incubating them in the presence of KNO_3 and its levels varied among wheat varieties (Table V).

A long lag phase has been reported for the induction of NR in the embryos from the germinating seeds of barley (Gupta et al., 1988). Seeds were incubated in nitrate and at appropriate times embryos were removed from the seeds to estimate the enzyme activity. In to this scheme, in the present set of experiments, embryos were first excised and then incubated in nitrate. Study of NR induction in the excised embryos showed a significant level of the NR activity as early as 4 h of germination. After this, the enzyme activity increased and showed a peak at 12 h of incubation

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(Table V) followed by a decrease in the level of the enzyme activity which came to the minimum activity after 36 h of incubation. It is interesting to note that the embryos of ungerminated wheat seeds of both varieties could not synthesize NR in the presence of 60 mM KNO3 after 12 induction. Since wheat seeds germinate in the absence of nitrate and without NR synthesis, seed germination is not depended on nitrate assimilation in the embryo. In the embryos present in the seed, i.e.along with the endosperm, there was no activity till 24 h of incubation.

It appears that in the attached embryos (i.e. within the seeds), the presence of the endosperm inhibited the induction of NR during the first 24 h of germination of PHS-tolerant wheat seeds. While in the attached embryos of PHS-sensitive wheat seeds NR activity detected in the early hours of germination. **Thus, the inhibitory effect of PHS-tolerant seed endosperm seemed to be specific for NR induction, a trait which could be used as a marker of PHS-tolerant cultivars.** Other enzymes of nitrate assimilation pathway, such as nitrite reductase, NiR, (Table V), glutamine synthase and glutamate dehydrogenase were also found to be present in attached embryo right from the initiation of germination in wheat (Gilmanov et al., 1988). Therefore it appears that only NR shows a long lag period among the key enzymes of nitrate assimilation, and this effect is exerted by the endosperm for NR only.

Table V. NR and NiR activities of attached and detached embryos of tolerant and sensitive PHS wheat seeds.

	PHS-tolerant, Lutescence 70				PHS-sensitive, Novosibirskaia 67			
Incubation time (h)	attached embryos		detached embryos		Attached embryos		detached embryos	
	NR	NiR	NR	NiR	NR	NiR	NR	NiR
12	0.0	8.5	4.3	22.5	0.7	17.6	5.2	23.7
16	0.0	10.3	3.5	22.0	1.2	18.7	5.0	21.4
20	0.0	15.5	2.7	18.6	2.4	21.8	4.3	18.0

Activity of NR in µmol NO^-_2 mg-1 protein hour-1.
Activity of NiR in nanomoles of NO^-_2 utilized mg-1 protein hour-1.

Since in PHS-tolerant seeds the presence of the endosperm delayed NR induction, attempts were made to study cross-effects of PHS-tolerant and PHS-sensitive endosperm extracts on the induction of NR in their detached embryos. Results of these experiments are shown in Table VI.

Table VI. Cross-effects of fresh PHS-tolerant and PHS-sensitive endosperm extracts on the induction of NR in their detached embryos after 12 h incubation with 60 mM KNO3 (every 4 h detached embryos were transfered to fresh endosperm extracts + KNO3).

Endosperm extracts and detached embryos combinations	NR activity in detached embryos
PHS-tolerant detached embryo in KNO3	4.5
PHS-tolerant seed endosperm + its detached embryo	0.5
Detached embryo of PHS-sensitive seeds in KNO3	5.5
Extract of PHS-sensitive seed endosperm + its detached embryo	2.9
Extract of PHS-tolerant seed endosperm + detached	1.9

embryo of PHS-sensitive seeds	
Extract of PHS-sensitive seed endosperm + detached embryo of PHS-tolerant seeds	0.9

The endosperm of PHS-tolerant wheat seeds contains a factor inhibiting NR induction by nitrate in embryo, while this factor is not present in PSH-sensitive cultivars. This inhibitory factor present in the endosperm gets gradually destroyed with time (Table VII).

Seed sensitivity of different wheat varieties to PHS depends on the levels of abscisic acid (ABA) in their endosperm and embryo, i.e. PHS-tolerant wheat seeds contain higher concentrations of ABA. On the basis of this fact we proposed that ABA regulates the activity or synthesis of NR in wheat embryo.

Table VII. Time course of decreasing NR inhibition in PHS-tolerant embryo by endosperm extracts (activity of NR in nanomoles of nitrate produced/embryo/h).

Endosperm extracted after	6 h	12 h	18 h	24h	30h
PHS-tolerant seeds	0.7	1.8	3.2	4.3	4.7
PHS-sensitive seeds	1.9	2.9	4.7	5.6	5.7

Detached embryos of PHS-tolerant seeds incubated for 12 h in the presence of different ABA concentrations plus 60 mM KNO3. Increasing concentrations of ABA increasee the inhibition of NR activity in detached wheat embryo.

Table VIII. Time course decrease of NR activity in PHS-tolerant embryo by increasing concentrations of ABA (activity of NR in nanomoles of nitrate produced/embryo/h).

ABA concentrations	Control	10nM	100nM	10μM
NR activity	4.8	4.3	3.5	1.3

When 10μM and 100μM ABA were added to fresh endosperm extracts of PHS-tolerant and –sensitive seeds and kept for 30 h at room temperature, the endosperm extracts of both seed types prevented the NR-inhibiting activity of the endosperm factor. Added ABA dissolved in the extract had still high NR-inhibiting activity after 30 h at room temperature (data not shown). In this experiments the endosperm of PHS-sensitive seeds were more effective in the inactivation/oxidation of ABA. The endosperm of PHS-sensitive seeds may contain higher concentrations of ABA-inactivating enzymes than the PHS-tolerant seeds, and this is one of reasons of PHS-sensitivity of wheat seeds.

These observations are significant in view of the fact that NR is induced in wheat seed embryo linked to the seed tolerance to PHS. The inhibition of NR in detached embryos following 4-6 h of imbibition by endosperm extract may serve as an early marker of the tolerance of wheat seeds to PHS.

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D. Scientific Impact of Collaboration

Since pre-harvest sprouting (PHS) is the result of the incapacity of the seeds to either produce ABA or to respond to it. This makes the recognition of markers of PHS sensitivity or tolerance of great importance for the screening of new cultivars of wheat in the cereal producing countries of Central Asia. This work has been the product of tight and fruitful cooperation between Israeli and Kazak investigators in Sede Boqer and Astana.

E. Description of Project Impact

PHS was one of the factors which contributed to the collapse of the Soviet economy, due to its massive damaging effect on the grain/flour producing capacity of the country. Today Kazakhstan, as a large grain producer, still suffers from the PHS effects and in a large scale. The ability to rapidly select PHS-tolerant cultivars and to introduce (where required) adequate Mo fertilization may bring to a rapid control of the problem, resulting in higher grain yields per unit land.

F. Strengthening of Developing Countries Institutions

Dr. Alikulov´s laboratory at the Gumilev Eurasian State University of the capital city Astana is a model of modern equipment and active staff of young scientists and doctoral students. This has been achieved by the scientific initiative of Dr. Alikulov and the support of three projects funded by the AID/CDR/CAR program (**CA15-024** - Molybdoenzymes and stress resistance, **CA17-018** Phytoremediation of soils contaminated with heavy metals and radionuclides, and the present **CA20-036** - The prevention of pre-harvest sprouting). Thanks to this support by AID funding and a successful cooperation between the investigators involved in these projects, the Department is successfully dealing with a number of agrobiology aspects related to food production in arid areas, and combating desertification by reclaiming crop production areas lost to environmental pollution and salinity.

G. Future Work

Work will continue as outlined in the aims of the project. The availability of PHS tolerant and sensitive wheat cultivars provided by the N. Baraev Cereal Research Institute in Shortandy will greatly facilitate: (a) the rapid and effective identification of new PHS-tolerant cultivars and (b) the study of the mechanism which prevent ABA accumulation in seeds to establish their dormancy or identification of the factors which render the seeds insensitive to ABA signals to impose dormancy.

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Section II

A. Managerial Issues
No problems for the moment.

B. Budget - None

C. Special Concerns - None

D. Collaboration, Travel, Training and Publications
Even at this early stage of the work, it seems that promissing results already available may serve as the basis for 1-2 scientific papers. Dr. Alikulov will be in Sede Boqer from February to September 2002, as will also a Kazak postdoctoral fellow. The Israeli investigators will visit Astana during 2002, presumably immediately after Alikulov's visit to Sede Boqer.

E. Request for A.I.D or BOSTID Actions – None.