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Integrated crop solution as new approach to combine genetics and other innovative inputs in wheat varieties development

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Abstract. Syngenta is, a leading company in agribusiness with operations world-wide. Syngenta implemented the concept of "integrated crop solution" years ago in order to give concrete answers to the growers, in terms of availability of complete, innovative, and easy to manage solutions in agricultural practises, to meet the market requirements in term of yield and food safety. For field crops such as wheat, the concept is carried out establishing a link between genetics, breeding, crop protection and agronomical know-how during different stages of wheat varieties development, focusing on the synergy of all combined technical inputs. One of the most interesting example is the development of durum wheat varieties with enhanced tolerance to *Fusarium* head blight, that was screened evaluating the combined synergic response with different fungicide applications on disease level symptoms and mycotoxins content. Other ongoing goals in cereal breeding focus on combining genetics, crop enhancer products, and growth regulators; these different approaches can achieve relevant results in terms of resistance to biotic and abiotic stress acting, for example, on root development and biochemical modification for an improved tolerance to soil and environmental adverse conditions in optimal balance with yield and quality requirements.

Keywords. Crop solution – Agr business – Disease tolerance – Fusarium spp. – Abiotic stress – Growth regulators – Seed care – Wheat varieties.

Solutions intégrées pour les cultures comme nouvelle approche pour combiner la génétique et d'autres moyens innovants dans le développement des variétés de blé

Résumé. *Syngenta est un leader dans le secteur de l'agro-industrie avec ses entreprises répandues dans le monde entier. Syngenta a mis au point le concept de « solution intégrée pour les cultures » il y a quelques années, visant à donner des réponses concrètes aux producteurs, à travers des solutions de pratiques agricoles complètes, innovantes et faciles à gérer, pour répondre aux exigences du marché en termes de rendement et de sécurité alimentaire. Pour les grandes cultures telles que le blé, cette démarche est réalisée en conjuguant génétique, sélection, protection des cultures et savoir-faire agronomique dans les différents stades de développement des variétés de blé, en mettant l'accent sur la synergie de tous les moyens techniques combinés. Un des exemples les plus intéressants est l'obtention de variétés de blé dur chez lesquelles a été améliorée la tolérance à la fusariose de l'épi, évaluée en considérant la réponse synergique combinée, dans le cas de différents traitements fongicides, sur le plan des symptômes de la maladie et de la teneur en mycotoxines. D'autres objectifs fixés pour la sélection des céréales concernent la combinaison multiple de gènes, les additifs des cultures et les régulateurs de croissance ; ces différentes approches peuvent produire des résultats pertinents en termes de résistance aux stress biotiques et abiotiques en intervenant, par exemple, sur le développement des racines et la modification biochimique en vue d'améliorer la tolérance aux sols et aux conditions environnementales défavorables dans un équilibre optimal avec les exigences de rendement et de qualité.*

Mots-clés. *Solution pour les cultures – Agro-industrie – Tolérance aux maladies – Fusarium spp., stress abiotique – Régulateurs de croissance – Protection des semences – Variétés de blé.*

I – Introduction

The concept of integrated crop solution when applied to varietal development of all arable and specialty crops, can be considered as an innovative approach to enlarge the possibility of the use of genetics to meet targets in terms of adaptation and performance.

Syngenta's worldwide expertise in many crops addresses the research and development efforts combining the know-how of its seeds and crop protection corporate departments in finding integrated and scalable solutions to maximize the plant potential of different crop species in balance with sustainability of the practices developed.

One the most relevant example is the diseases tolerance of varieties; the introgression of most complex resistance traits and the associated genetic loci (QTLs) coming from conventional breeding bring relevant benefits for the genetic material in terms of *Fusarium* head blight (FHB) resistance or tolerance. The higher number of QTLs introgressed the greater the resistance to FHB, but the stack of many QTLs also increases negative traits such as low protein quality, low yield, low gluten index, etc.

However, unfortunately, some disease reactions are difficult to reliably score, while others are highly sensitive to the environment; a variety with good resistance in one location may be unacceptably susceptible in another.

For these reasons, by combining tolerance traits, proper fungicide applications, and good agronomic practices in field, it is possible to achieve interesting practical results in terms of crop protection, crop safety, quality, and yield in a wide range of conditions where only the varieties features could not be sufficient to ensure the general crop performance.

Other crop solution in wheat can be identified with the growth regulator (GR) application to further improve the approaches of conventional breeding relating to the development of drought-resistant varieties. These aspects could be referred to the chemically-induced resistance in plants, that in its broadest sense, is well-known and has been studied for a long time both on mono- and di-cotyledoneae species. This induction is responsible for the expression or the overexpression of certain genes that can potentially increase the resistance to biotic factors but also for some abiotic factors such as drought, frost, etc.

Although high yield potential is a main target of most cereal breeding programs, this cannot be always considered compatible, for example, with high levels of drought resistance (DR). The observation and the studies during variety development concerning in-field GR application can rebalance the inverse relationship between yield potential, DR, water-use efficiency, and other relevant genetic traits linked to abiotic stress tolerances.

GRs are normally used at farm level in cereals to reduce the height and to strengthen the stem; thus leading to an increase in resistance to lodging; some of them, as trinexapac-ethyl (Moddus®), when applied at early stage, can improve root growth especially in non-optimal growing conditions with water shortage or reduced nutrient fertilizers, returning traits of "hardiness" in phenotypes potentially suited to high yields.

Is also known that DR can be positively influenced by the radical health care provided by the use of seed treatments and foliar fungicides applications as some triazoles, strobilurins and SDHI fungicides, that combine the effects of disease control with a physiological action on plants by improving dehydration avoidance and osmotic adjustment and preventing the effects of early senescence of leaves due to partial slowing of ethylene biosynthesis.

II – Wheat genetic disease resistance and FHB – mycotoxins management with integrated crop solutions

It's a common understanding that the durum species is more sensitive for certain kind of fungal diseases than other species of *Triticum* genus and all its types of active resistance mode of actions are considered less effective.

Due to the high sensitivity of this species to the diseases and the potential risk of mycotoxins pollution on grains, in certain agricultural settings according to climate, crop rotations, soil tillage, etc, FHB resistance/tolerance is one of the most important targets for durum breeding.

Moreover, as already mentioned, the introduction of specifics QTLs for diseases tolerance within genotypes may be associated with non-positive traits whose phenotypic expression would not lead to a high value of the varieties developed. To modulate all this kind of disadvantages, the combination of resistant varieties with other inputs as chemical control of disease showed successful results.

For this reason many efforts have been directed towards enhancing the effects resistance induction on FHB, not only based on Durum genetics improvement; fungicide applications with active ingredients with proven efficacy and selectivity, if applied at the right time in the field, can reduce with high significance the mycotoxins content induced by the pathogens, even in situations of higher risk, where only the genetic tolerance would not be able to provide an absolute absence of phytosanitary risk.

This risk is universally recognized and it depends in particular, on crop rotation and tillage used, as shown in figure 1.

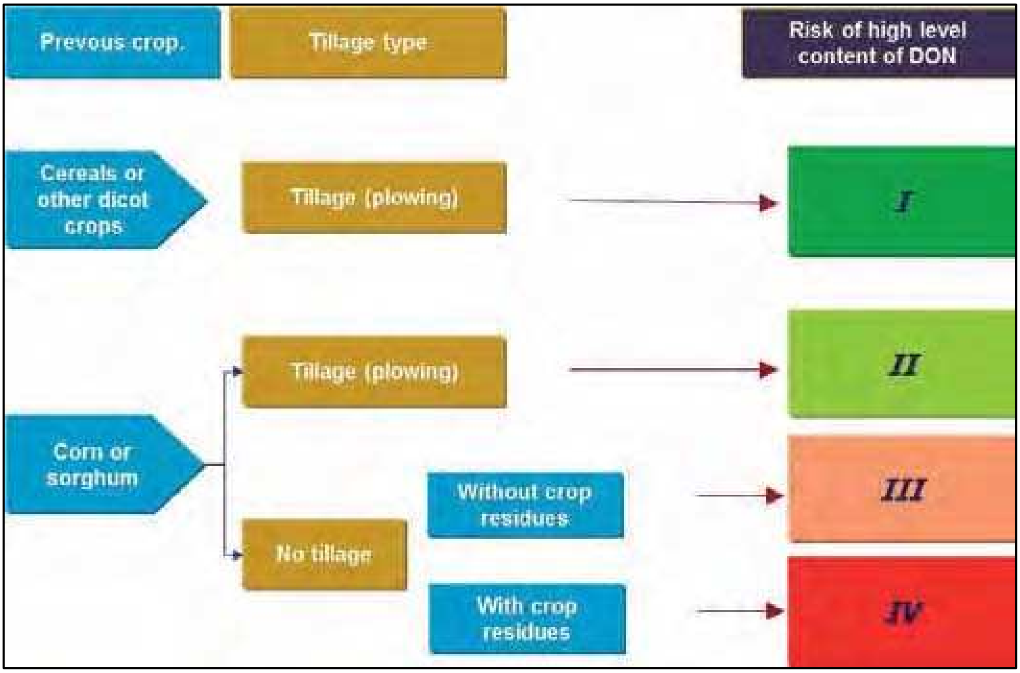

Figure 1. Definitions of the 4 levels of agronomic risk for DON levels on the wheat yield.
(source Arvalis –modified)

Theoretically, this experimental evidence is not only linked to a possible additive effect of the combination of tolerance-fungicidal efficacy, but also to an enhancement of FHB resistance mechanisms active within the plant, in particular of those of type 2 and 3 that indicate the resistance to the fungal growing inside the head and the resistance to colonization of grains.

Accordingly, with these indications, a good example of crop solution approach on FHB tolerance can be considered the seed dressing practice. Applications made directly on seeds with specific fungicides, can oppose the effect of the endogenous migration of *Fusarium graminearum* from seed to the ear in field. Several studies have shown that for the control of this pathogen that develops on culms in growth, the use of seed dressing can also significantly reduce the detectable level of deoxynivalenol (DON) on the ear, particularly in high-risk agronomic situations.

In situations of risk identified with levels 3 and 4 (Fig. 1), the use of a FHB-resistant variety is highly recommended but this would not necessarily entail absolute safety with respect to the DON content in terms of law.

The synergy between tolerance to FHB and seed dressing, as shown in figure 2, would bring a further lowering of the level of DON close to 20% and more in situations of higher risk, giving a wider safety range to the combined solution variety–seed care at field level.

As shown in figure 3, the contribution of the variety in common wheat for the management of the FHB problems is essential, because the variety considered sensitive, if referred to the resistant variety (Illico), in the field trials carried out, appears to have a 39 times higher potential for accumulation of DON. Moreover, also mid-sensitive varieties showed to have this 2-4 times greater potential compared to Illico. In extreme high-risk conditions this difference may further increase.

Still focusing about the levels of agronomic risk previously mentioned on the incidence of FHB foliar treatments with fungicides at the flowering stage are effective to minimize the risk of high incidences of disease.

In figure 4, we can highlight the fact that in a high-risk situation, this differential between the accumulation of a variety FHB sensitiveness with respect to a resistant one, can be up to a factor of 85. In this case the application of specific fungicides for the control of FHB further contributes to lower the content of mycotoxins to greater safety levels.

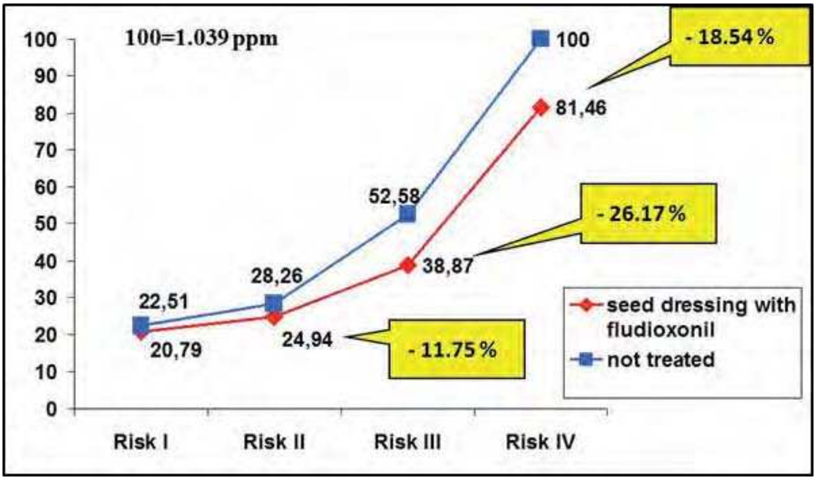

Figure 2. DON content on durum wheat yield (average of 13 trials carried out in France) in different agronomic risk level using fludioxonilvs untreated seed.
(source Syngenta internal)

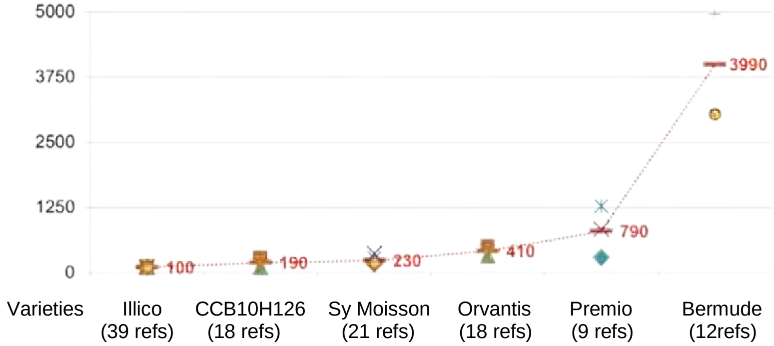

Figure 3. Winter wheat varieties evaluated in terms of DON content in 7 different locations in France during 2012. *Illico is the resistant reference, base 100 of DONon all trials; Bermude is the most sensitive , accumulation of 39.9 more DON than Illico***.**
(source Syngenta internal)

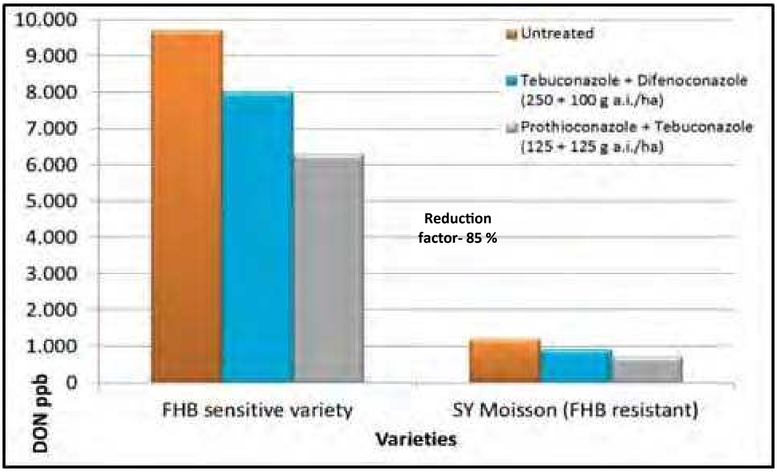

Figure 4. Two winter wheat trials with average DON content in extremely high-risk agronomic conditions (level IV) for FHB incidence. Interaction with fungicide application at flowering stage. Comparison between 2 varieties .
(source Syngenta internal)

In Durum wheat these differences tend to amplify and the management of an acceptable level of DON is very critical. Varieties with traits of good pest resistance become essential for those reasons, especially within certain agricultural conditions to get down the level of higher risk.

Figure 5 shows the high level of severity of attack by FHB and the significant difference between the expression of the symptoms on the ear with and without the artificial inoculation of the pathogen found on more sensitive varieties.

In these situations, the contribution of an integrated solution as seed dressing and foliar fungicide application can stabilize the results of the plant protection; even on more tolerant varieties the result is often greatly improved. Obviously, the integrated approach must also consider the agronomic management of the crop on the choice of the type of tillage and crop rotation, in order to bring the level of risk of contamination by DON and other mycotoxinsas as low as possible.

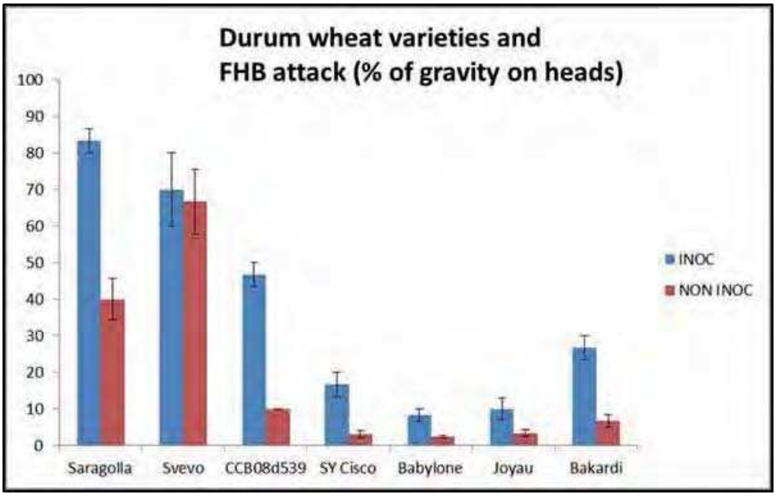

Figure 5. Different sensitivity to FHB of some durum varieties with and without artificial inoculation -2012 .
(source Turin University and Syngenta)

III Interactions with genetic drought resistance and application of grow regulators (GR) and fungicides in wheat

The application of GR on crops, as already mentioned, can potentially have different types of advantages for the cultivation of wheat varieties with traits of quality and productivity of high interest. In addition to the prevention of the lodging, which is the typical result expected from the use of these products in the field, some active ingredients showed the peculiarity of having a positive influence on the root system development.

Although the genetic trait of resistance to drought is characterized by the high complexity of phenotypic response, the practical experiments conducted on uses of GR as Trinexapac-ethyl, constantly appear in an improvement of the root development state, especially in the most critical situations for the absorption of water and nutrients. This possibility of self-regulation of the root system development as a function of water stress is important for the benefit that this kind of physiological adaptation can meet in terms of vegetative response.

As reported in figure 6, in many trials conducted over several years in various parts of the world with extensive cereal cultivations, the results of the use of Trinexapac-ethyl highlights, in general terms, a reduction of internodes width, especially of those lower down, and a clear increase in the root system development. Moreover, in most of the cases observed, an improvement of tillering and an increased level of filling of the grains is possible and this clearly helps a yield increase.

This results would lead to an interesting practical answer to the dilemma of the drought-resistant ideotype which is sometimes considered opposed to the expression of a high yield potential.

During the last few years interesting results were also acquired concerning drought resistance as a secondary effect obtained by the use of fungicides belonging to different chemical groups. In the specific field tests dedicated to examining these aspects, on plots treated with Isopyrazam (IZM) a significant improvement of some biochemical and physiological parameters was observed, with reference to the conditions of water availability on irrigated wheat varieties under test.

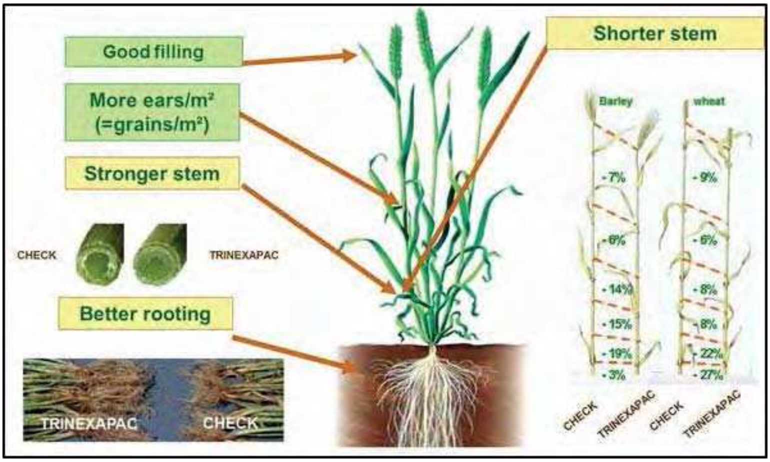

Figure 6. Anti-lodging and other effects of Trinexapac-ethyl applications in cereals. The effect on root development in drought conditions can improve the adaptation of varieties without relevant traits of water-use efficiency mechanisms.
(source Syngenta internal)

Entering into detail of this issue, Figure 7 shows the results of an experiment where the application of Isopyrazam (SHDI chemistry) in a standard protection program of the main fungal diseases such as powdery mildew and Septoria, showed an improvement in the size of the leaf area with a consequent increase in the efficiency of vegetative conditions where water availability was lower.

This positive physiological situation was determined measuring the relationship between electron transport rate (ETR) and the photosynthetic active radiation, both linked to photosynthetic efficiency.

As shown in Figure 8, the ETR is reduced under drought conditions. ETR was assessed on the flag leaves using chlorophyll fluorescence techniques; the difference between the ETR factor is particularly clear in the plots where the crop was maintained under conditions of water scarcity.

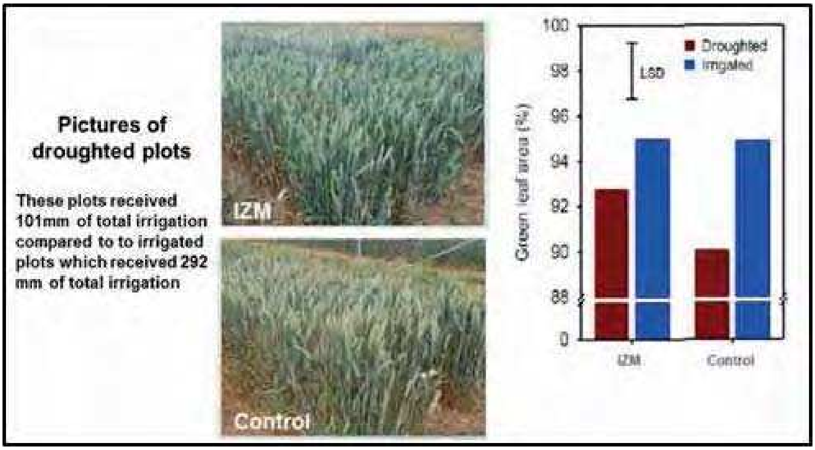

Figure 7. Effects on green leaf area in drought and irrigated conditions of Isopyrazam (SDHI fungicide) application in wheat for disease control purpose on Solstice variety.
(source Rothamstedand Syngenta)

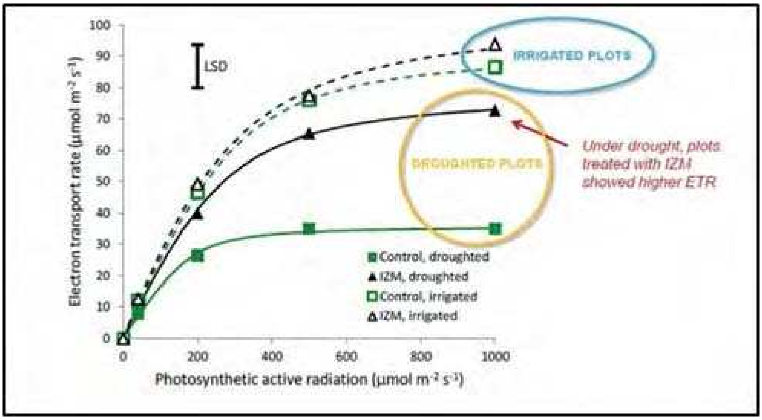

Figure 8. Effects of Isopyrazam (SDHI fungicide) application in wheat for disease control purpose on the photosynthetic efficiency in wheat (var. Solstice).
(source Rothamsted and Syngenta)

IV – Conclusions

As noted in several aspects, the possibilities that the implementation of integrated crop solutions might lead to interesting contributions in order to improve the activity of development of new wheat varieties of agronomic interest and for food downstream are manifold.

The combination of integrated crop solution and breeding with introgression of traits and their associated QTLs can lead to further benefits in durum wheat varieties development with high levels of quality, productivity, and food security, “correcting” any failure in order to achieve optimal characteristics and introducing more stable performances in different situations and crop conditions.

If verified during the early stages of varietal development, these integrated inputs, together with the use of correct agronomic practices, can lead to a speedup of the development process and to the possibility of a wider adaptation of varieties with benefits in terms of costs and enhanced responsiveness to the market needs.

One possibility offered by the integrated crop solution is to provide farmers for each variety developed, with a precise “user guide” to maximize the performance in different environments, optimizing all aspects of crop management in terms of costs and overall sustainability of cultivation practices. It is also important to consider the effectiveness and the role of integrated crop solutions to promote stronger connections among different expertise; through a close collaboration between breeders, agronomists and plant pathologists, exploration in cereals variety development may achieve important benefits in all situations but especially in critical ones where the growing demand for food, environmental deterioration, low sustainability levels, and climate changes threaten the entire social system of rural communities.

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