Determinants of research productivity of agricultural scientists: implications for the national agricultural research and education system of India

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A micro level analysis for understanding the major determinants of research productivity of individual scientists in the National Agricultural Research and Education System of India was undertaken. A sample of two hundred scientists was drawn through multistage disproportionate stratified random sampling from a high performing and a low performing agricultural institute in India. Forced choice Q-sort technique was employed to record perception of respondents regarding relative influence exerted by selected variables on their research productivity and a factor analysis using principal component method with varimax rotation helped in extracting 11 major factors determining research productivity of agricultural scientists, namely, organizational research environment, creativity, perseverance and commitment, research facility, ability to work under constraint, incentive policy, proactiveness, purpose-driven orientation, achievement motivation, involvement in teaching and job satisfaction. The apparent uniformity in percentage variance contribution of these 11 factors implies that optimum research productivity of scientists can only be harnessed when personal and organizational factors work in harmony.

Keywords: Agriculture, determinants, productivity, research, scientists.

RESEARCH productivity has been a widely discussed issue among scientists, researchers, administrators and policy makers throughout the world. The growing concern over research productivity of scientists in general and agricultural scientists in particular will further concentrate with the ever-increasing challenges in different forms, such as restoring ecological balance, sustaining natural resource base in the grim context of climate change and thereby securing food for all. Enhancing efficiency of the National Agricultural Research and Education System (NARES) of the country is therefore an indispensable task ahead to be performed within a short period of time.

The NARES of India, mainly governed by the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) is one of the largest national agricultural research systems in the world. Technologies and scientific publications are regarded as the two major outputs of scientists employed under NARES which has so far shouldered the responsibilities of research, extension and education in agriculture and allied fields in the country and immensely contributed towards achieving self-sufficiency in food production. In technological front, the green revolution technologies which promoted self-sustaining economic growth and alleviated poverty in Asian countries to a great extent, were exemplary and globally recognized. It is estimated that the real per capita income in Asian countries almost doubled between 1970 and 1995 and the poverty ratio significantly declined from 60% to about 30% during the same period[1]. As far as scientific publication is concerned, it is noteworthy that in India the highest contribution (26.4%) to the total number of published research papers is made by scientists working in agriculture including forestry, fisheries, and animal husbandry[2]. This seems highly impressive in the national context, although in the global context the picture is not that rosy. As far as India's share of world research output in various disciplines is concerned, it is important to note that among all disciplines, the share of agricultural sciences including plant and animal sciences has shown the largest decline between 1981 and 2010 (ref. 3). Besides, a very high degree (>60%) of non-citation of research papers generated from agricultural, plant and animal research continues to be a major concern[4]. NARES has also received criticisms on several

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occasions for the reason that, except for some scattered significant research outputs from some limited research institutes under the ICAR, there has hardly been a major technological breakthrough in agricultural research since green revolution.

India continues to be an agrarian based demography and economy as well. The contribution of agriculture and allied sectors to the total GDP of the country is still high (13.9% in 2013–14)[5]. Although 50–60% of the workforce is still engaged in this sector, productivity of majority of the crops and livestock remains low. It has to be remembered that although information technology (IT) based gadgets have reached almost every remote corner of the country, diffusion and internalization of improved agricultural technologies in large majority at the farmers' fields still remain a challenge. One in every five Indians till date earns less than one dollar a day although four out of every five Indians use a mobile phone[6,7]. Poverty, hunger and associated problems are much more prevalent in rural areas where the majority of population is engaged in farming activities. Therefore, to eradicate poverty, hunger and malnutrition and to reach the millennium development goal of the United Nations, it is imperative to achieve higher growth rate in agriculture which is hardly possible without achieving largely improved efficiency in agricultural research and development in the country. In this context, it is alarming to note that research and development efforts undertaken by the third world countries may soon fall into a 'technological orphanage'[8].

Individual scientists working under NARES are responsible for its overall output. It is quite obvious that not all NARES scientists are able to produce the same quality and quantity of output from research. There have to be certain differences among NARES scientists both in access of prerequisite organizational support and possession of some pro-research personal attributes which make the difference in research productivity. Earlier researchers took a lot of efforts to study how life cycle conditions research productivity[9–11] although in the Indian context there have been limited initiatives in this particular regard. The present article is based on a research study undertaken at micro level to develop a deep understanding of the major determinants of research productivity of agricultural scientists. An attempt has been made to draw policy implications of the same for the NARES scientists.

Methodology

The study was conducted with a sample size of two hundred ($n = 200$) agricultural scientists randomly drawn from different strata of a high performing agricultural institute – ICAR-Indian Agricultural Research Institute (IARI), New Delhi and a low performing agricultural institute – Chandra Sekhar Azad University of Agriculture and Technology (CSAUA&T), Kanpur. It has to be mentioned here that the categorization of institutes (high performing and low performing) and further validation of the same was based upon previous studies[12,13].

A systematic analytical procedure[14] was followed to reach conclusions regarding the major determinants of research productivity of agricultural scientists. First, a total of 133 variables related to research productivity were collected through literature and holding preliminary discussions with agricultural scientists of different strata. To overcome ambiguity, restructuring and repetition, the collected variables were thoroughly scrutinized in consultation with experts and 60 variables were finally retained. A forced choice Q-sort technique[15] was thereafter applied to record perception of respondent agricultural scientists regarding relative importance of the 60 finally retained variables in terms of influencing their research productivity. In this process, all 60 variables were printed on 60 separate rectangular cards which were given to respondents along with a rank sheet containing 9 categories, namely, most important, highly important, very important, quite important, somewhat important, slightly important, little important, very little important and least important. The respondents were personally interviewed and asked to sort out respectively 2, 3, 7, 11, 14, 11, 7, 3 and 2 numbers of variables among the 60 finally retained ones into these 9 rank ordered categories based upon their perception regarding relative importance of the variables to influence research productivity.

The Q-sorted perception of the respondents was quantified through median analysis. A factor analysis using principal component method with varimax rotation was undertaken to isolate common factors underlying the variables and for scientific parsimony in interpretation.

Results and discussion

Agreement among groups of respondents regarding the Q-sorted perception

As worked out, value of the Kendall's coefficient of concordance was found to be 0.73 which implies that the extent of agreement among the several groups of respondents was as high as 73%. A highly significant Chi square value (χ^2 (59) = 8.617E3, $P < 0.01$) indicates that there was statistically reliable agreement among the several groups of respondents under study regarding the perceived degree of importance of the variables that influence research productivity (Table 1). This may be due to the fact that although the cadres and institutes differed, the respondents basically had to perform similar jobs in their profession, such as teaching, research and extension. Therefore, the experience, professional requirements, and overall outlook of the agricultural scientists of the two different institutes were similar and the same was reflected in assigning relative importance to the

Table 1. Coefficient of concordance (Kendall's *W*) and its test of significance ($n = 200$)

Groups of respondents	Degree of agreement Kendall's W	Test of significance Chi square
Associate professors (LPI), Professors (LPI), senior scientists (HPI) and principal scientists (HPI)	0.73	8.62E3**

**Significant at 0.01 level of probability.

Table 2. Distribution of relatively important 26 variables influencing research productivity of agricultural scientists ($n = 200$)

Category	Degree of importance	Variable	Median score range
Psycho-social	Most important	Achievement motivation	7.5–8.5
	Very important	Proactive behaviour	5.5–6.5
		Time utilization pattern	5.5–6.5
	Quite important	Commitment	4.5–5.5
		Creativity	4.5–5.5
		Curiosity	4.5–5.5
		Intelligence	4.5–5.5
		Perseverance	4.5–5.5
		Purpose orientation	4.5–5.5
		Sense of responsibility	4.5–5.5
Psychomotor	Very important	Skill in communicating results of research work	5.5–6.5
		Working over-time	5.5–6.5
	Quite important	Ability to get fund for research	4.5–5.5
		Ability to work under constraints	4.5–5.5
		Self evaluation of own scientific performance	4.5–5.5
Organizational	Highly important	Involvement in teaching	6.5–7.5
		Scope to conduct interdisciplinary research	6.5–7.5
	Very important	Organizational climate	5.5–6.5
	Quite important	Adequacy of modern technological tools	4.5–5.5
		Adequate fund for research	4.5–5.5
		Adequate infrastructure to conduct research work	4.5–5.5
		Job satisfaction	4.5–5.5
		Adequate salary	4.5–5.5
		Number and quality of research students/assistants working with	4.5–5.5
		Recognition to efficiency, honesty and hard work	4.5–5.5
		Transparent/impartial organizational policy	4.5–5.5

variables under study by them. As the groups did not significantly differ in their perception as mentioned, there was no need to conduct a principal component analysis (PCA) separately for the four groups. Hence, in the present study, the PCA was carried out with the pooled data.

Variables influencing research productivity: perception of the pooled sample

The variables influencing research productivity of agricultural scientists belonged to different categories, e.g. psycho-social, psychomotor, demographic, organizational and environmental. A median analysis helped in distributing the 60 variables under study into 9 rank ordered categories. The variables occupying the uppermost four categories, namely, most important (7.5–8.5), highly important (6.5–7.5), very important (5.5–6.5) and quite important (4.5–5.5) were considered relatively important to determine research productivity. A total of 26 variables were thus found to be relatively important, which only were considered significant for a PCA (Table 2). The relatively important variables evolved during this study were mainly of two kinds – organizational and personal and the same was reported in some other studies too[16]. As indicated by the calculated median values of each of the variables, 'achievement motivation' was considered the most important and 'fatalism' the least important among the 60 variables influencing research productivity.

Major factors of research productivity: excerpts from a PCA

In order to extract the underlying factors of the variables under study, factor analysis was undertaken with the relatively important 26 variables. The results of the factor analysis have been reported in Tables 3 and 4. At the outset, it should be mentioned here that the total number of variables considered for factor analysis was less than

Table 3. Factor loading and communality (h^2) of variables, eigenvalues (λ) and variance contribution (%) of organizational factors of research productivity (n = 200)

Factor	Variable	Factor loading	Communality (h^2)	Eigen-value (λ)	Variance contribution (%)
I: Organizational research environment	Adequate fund for research	0.92	0.89	2.50	9.63
	Organizational climate	0.83	0.82		
IV: Research facility	Adequacy of modern technological tools	0.53	0.85	2.20	8.48
	Adequate infrastructure	0.76	0.88		
	Scope to conduct interdisciplinary research	0.66	0.87		
	Number and quality of students/RAs working with	0.62	0.84		
V: Incentive policy	Adequate salary	0.89	0.88	2.09	8.02
	Recognition to honesty, efficiency and hard work	0.49	0.85		
	Transparent/impartial policy	0.49	0.81		
X: Involvement in teaching	Involvement in teaching	0.93	0.94	1.78	6.85
XI: Job satisfaction	Job satisfaction	0.86	0.89	1.43	5.48

Table 4. Factor loading and communality (h^2) of variables, eigenvalues (λ) and variance contribution (%) of personal factors of research productivity (n = 200)

Factor	Variable	Factor loading	Communality (h^2)	Eigen-value (λ)	Variance contribution (%)
II: Creativity	Creativity	0.87	0.85	2.26	8.68
	Intelligence	0.66	0.87		
	Curiosity	0.61	0.84		
III: Perseverance and commitment	Perseverance	0.90	0.92	2.22	8.52
	Commitment	0.76	0.84		
	Sense of responsibility	0.63	0.89		
VI: Ability to work under constraint	Ability to work under constraint	0.82	0.77	2.01	7.74
	Ability to get fund for research	0.61	0.94		
VII: Proactiveness	Proactive behaviour	0.86	0.87	1.94	7.46
	Skill to communicate research outcome	0.74	0.78		
	Time utilization pattern	0.47	0.89		
VIII: Purpose driven orientation	Working overtime	0.88	0.84	1.93	7.42
	Purpose orientation	0.53	0.86		
IX: Achievement motivation	Self-evaluation of own scientific performance	0.81	0.79	1.83	7.04
	Achievement motivation	0.61	0.73		

30, and the mean communality value (0.85) of the 26 variables after extraction was greater than 0.7. Therefore, Kaiser's criteria[17] was followed to retain only those factors with eigenvalues equalling or exceeding 1.00. A total of eleven factors, all having eigenvalues greater than 1.00 have been reported. Only those factor loadings of 0.3 or more have been considered significant and taken into account for reporting[18–20]. Among the 11 factors yielded by the factor analysis, 5 were organizational and the remaining 6 were personal factors.

Organizational factors

The organizational factors of research productivity altogether contributed to 38.46% of the total data variability. They have been discussed below:

Factor I: organizational research environment: The first factor could be explained by two organizational variables, namely adequate fund for research and organizational climate. The variable organizational climate in the context of research indicates whether the organization provides congenial research environment to its scientists or not. The other variable underlying factor I entails a very basic requirement, i.e. whether the organization fosters adequate financial support to sustain that particular environment or not. The factor was termed as 'organizational research environment' and it is evident that a very strong relationship exists between work and academic environment, organizational culture and socialization, research expectation and research productivity[21,22]. The factor contributed the highest variance (9.63%) in total variability (Table 3).

Factor IV: research facility: 'Research facility' was the next important organizational factor constituting of four variables namely, adequacy of modern technological tools, adequate infrastructure, scope to conduct interdisciplinary research, and the number and quality of students and research associates working with. Research productivity is largely contributed by the number of graduate and doctoral students guided[23,24]. The second constituting variable of the factor 'scope to conduct interdisciplinary research' clearly brings into discussion the inevitable role of research collaboration which is a major contributing factor to research productivity, as considered since long[25]. This factor was able to explain about 8.48% of the total data variability.

Factor V: incentive policy: Money and recognition are very important determinants of research productivity[26]. Factor V comprised three variables namely, adequate salary, transparent/impartial policy, and recognition to honesty, efficiency, and hard work. The first two variables underlie hygiene factors and the third one is a motivator[27]. These three variables seem to consider inducement strategies of an organization. The term 'incentive policy' was considered tenable to explain this factor. Out of the total variability in data, factor V contributed 8.02%.

Factor X: involvement in teaching: Only one variable – involvement in teaching accounted for the factor X. Teaching has always been perceived as an influential factor contributing to research productivity. Although moderate level of teaching enhances research performance[28], teaching load may act as a hindering factor to research productivity[24,29]. In the present study, this factor exerted 6.85% variance in total variability of data.

Factor XI: job satisfaction: The last organizational factor could also be explained by only one variable, i.e. job satisfaction. Factor XI accounted for 5.48% of total data variability.

Personal factors

The personal factors evolved during the present study had a total variance contribution of 46.85% in research productivity. They are discussed below:

Factor II: creativity: Three psycho-social variables, namely, creativity, intelligence, and curiosity were chosen for explaining Factor-II. All these three variables were supposed to share a common dimension, i.e. intellectual skill which is considered critical as far as research is concerned. The factor was termed as creativity. The results are in concurrence with the findings of some previous studies[14,30]. Factor II contributed about 8.68% variance in total variability of the data (Table 4).

Factor III: perseverance and commitment: Three variables, namely, perseverance, commitment and sense of responsibility were found to load significantly high on factor III. This factor contributed 8.52% in total variability of data.

Factor VI: ability to work under constraints: This factor consisted of two variables, namely, ability to work under constraint and ability to get fund for research. The factor could explain 7.74% of total variability.

Factor VII: proactiveness: Factor VII comprised three variables, proactive behaviour, skill to communicate research outcome and time utilization pattern. Conducting research does not serve its purpose until the practical implication of research outcome is made available in the public domain. This task is assumed to require a considerable amount of proactive approach. Timeliness of research publication is considered important in terms of relevance and research impact. The seventh factor was named as 'proactiveness' which contributed to 7.46% of the total variability.

Factor VIII: purpose driven orientation: Two variables, working overtime and purpose orientation were considered for interpreting this factor which accounted for about 7.42% of the total data variability. Scientists with high purpose orientation worked beyond office hours, worked at home and even on holidays. They were highly motivated to complete the tasks within the scheduled time. Time structure is positively influenced by a sense of purpose[31]. The factor was named as 'purpose-driven orientation'.

Factor IX: achievement motivation: Self-evaluation of own scientific performance and achievement motivation were the two variables chosen to explain factor IX. Achievement motivation is an intrinsic force that is supposed to trigger critical appraisal of self-performance to improve upon that. About 7.04% variability in the construct was contributed by this factor.

Conclusion and implications for the Indian NARES

The study identified eleven different factors determining research productivity of agricultural scientists; personal as well as organizational. In the light of these findings, it can be suggested that agricultural research institutions should strive to sustain their research environment by assessing the overall organizational climate at individual department level and at the institute level as a whole at regular intervals to improve on the climate dimensions, such as autonomy, innovation, leadership styles, trust, pressure, recognition, fairness and support along with allotting sufficient funds for individual in-house research projects. In this context, it is important to note that externally funded projects are good sources of securing research funds. Therefore, scientists can be encouraged and patronized by the research managers of individual institutes to obtain externally funded research projects. Among the other organizational factors identified, 'incentive policy' draws special attention as it undertakes rewarding strategy of the organization that has direct influence on achievement motivation of scientists. Research institutions should recognize efficient, honest and hard workers distinctly and must maintain fairness in their policies. A system of monetary and innovative non-monetary incentives for the high performers may be introduced in this regard. The present results clearly indicate that organizational factors alone cannot determine research productivity of scientists unless and until there is a functional role play of the personal factors identified. Therefore, agricultural scientists have to take necessary steps to continuously build on their personal attributes and research institutions should take care of these individual qualities to bolster individual and thereby organizational research productivity. The almost uniform distribution of the several factors in terms of their variance contribution to research productivity implies that optimum research productivity of scientists can be harnessed only when all the identified factors work in harmony.

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